PB 206 309

EVALUATION OF THE S. S. WHITE PANOREX X-RAY MACHINE

Arnold F. Jacobson, et al

U. S. Department of Health, Education and Welfare
Rockville, Maryland

December 1971

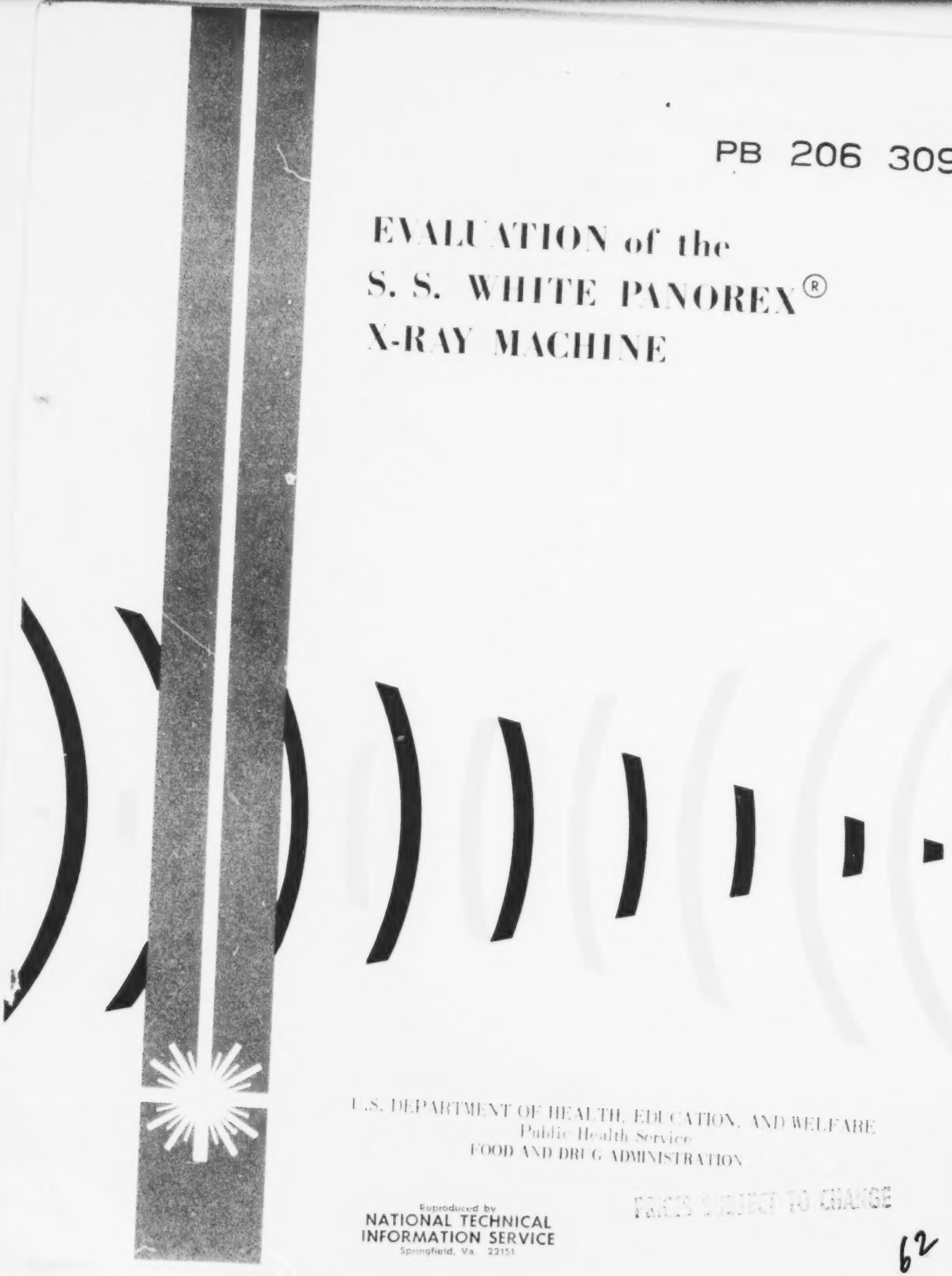
DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

PB 206 309

EVALUATION of the S. S. WHITE PANOREX® X-RAY MACHINE



U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
FOOD AND DRUG ADMINISTRATION

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

PRICES SUBJECT TO CHANGE

62

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle Evaluation of the S.S. White Panorex^{R} X-ray Machine BRH/DEP 72-6			5. Report Date December 1971 6.
7. Author(s) Arnold F. Jacobson and John P. Ferguson			8. Performing Organization Rept. No. BRH/DEP 72-6
9. Performing Organization Name and Address U.S. Department of Health, Education, and Welfare Bureau of Radiological Health Rockville, Md. 20852			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Department of Health, Education, and Welfare Bureau of Radiological Health Rockville, Md. 20852			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

An evaluation of the S.S. White Panorex^{R} dental x-ray machine was performed. The physical and operational characteristics of the unit were investigated with particular emphasis on kVp and mA meter calibrations, focal spot characteristics, x-ray beam dimensions, half-value layers, and inherent filtration. Isoexposure curves for radiation in the vicinity of a phantom were determined, and survey techniques for half-value layer measurements and x-ray beam alignment were investigated. Recommendations based on the observed operation of the Panorex are advanced.

17. Key Words and Document Analysis. 17a. Descriptors

Panoramic X-ray Machines; Radiation Safety; X-ray Machine Evaluation; X-ray Machine Safety.

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited Avail. Supt. of Docs. Price 65 Cents	UNCLASSIFIED	72
	20. Security Class (This Page) UNCLASSIFIED	22. Price

DIVISION OF ELECTRONIC PRODUCTS

Technical Reports

Technical reports of the Division of Electronic Products are available in microfiche at a price of $0.95 from the National Technical Information Service (NTIS) Springfield, Va. 22151. The PB number should be cited when ordering from NTIS. Paper copies are available from either NTIS or the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C. 20402, as indicated.

	Title
BRH/DEP 70-1	X-ray Emission from Cold-Cathode Gas Discharge Tubes Used for Educational Purposes (February 1970) (NTIS no. PB 189 890, $3.00)
BRH/DEP 70-2	Report of Tests Made on the Westinghouse Panoramic X-ray Machine (March 1970) (NTIS no. PB 190 199, $3.00)
BRH/DEP 70-3	Description and Evaluation of a Fluoroscopic Screen Visual Brightness Comparer (March 1970) (NTIS no. PB 190 870, $3.00)
BRH/DEP 70-4	Evaluation of a Sorelec-Pitchford Portaspec Portable X-ray Spectograph (March 1970) (NTIS no. PB 190 876, $3.00)
BRH/DEP 70-5	A Study of Head and Neck Exposures from Panoramic Roentgenography (March 1970) (NTIS no. PB 190 994, $3.00)
BRH/DEP 70-6	Laboratory Testing and Evaluation of Color Television Receivers Acquired During the In-Plant Survey (March 1970) (NTIS no. PB 191 090, $3.00)
BRH/DEP 70-7	A Comparison of Microwave Detection Instruments (April 1970) (NTIS no. PB 191 395, $3.00)
BRH/DEP 70-8	Development of Liquid Crystal Microwave Power Density Meter (May 1970) (NTIS no. PB 191 196, $3.00)
BRH/DEP 70-9	Product Testing and Evaluation of Giant Vision TV Projector (May 1970) (NTIS no. PB 191 906, $3.00)
BRH/DEP 70-10	Survey of Selected Industrial Applications of Microwave Energy (May 1970) (NTIS no. PB 191 194, $3.00)
BRH/DEP 70-11	Leakage Variations from Microwave Ovens (June 1970) (NTIS no. PB 192 042, $3.00)
BRH/DEP 70-12	The Effect of Instrument Averaging Time on Microwave Power Density Measurements (June 1970) (NTIS no. PB 192 122, $3.00)
BRH/DEP 70-13	Variability in the Automatic Processing of Medical X-ray Film (June 1970) (NTIS no. PB 192 702, $3.00)
BRH/DEP 70-14	Simple X-ray Detection Instruments for Television Service Technicians (June 1970) (NTIS no. PB 192 377, $3.00)
BRH/DEP 70-15	A Partial Inventory of Microwave Towers, Broadcasting Transmitters, and Fixed Radars by States and Regions (June 1970) (NTIS no. PB 193 542, $3.00)
BRH/DEP 70-16	Near Field Instrumentation (July 1970) (NTIS no. PB 192 748, $3.00)
BRH/DEP 70-17	Radiation Safety Surveys of X-ray Facilities Within the Federal Health Programs Service (July 1970) (NTIS no. PB 192 957, $3.00)
BRH/DEP 70-18	Bremsstrahlung Production (July 1970) (NTIS no. PB 192 288, $3.00)
BRH/DEP 70-19	Radiation Safety Surveys of X-ray Facilities Within the Bureau of Prisons During 1968 (July 1970) (NTIS no. PB 191 222, $3.00)
BRH/DEP 70-20	Investigation of the Response of the Microlite 287 Probe to Microwave Fields (August 1970) (NTIS no. PB 193 223, $3.00)
BRH/DEP 70-21	Evaluation of an X-radiation Dosimetry Service for Home Television Receivers (August 1970) (NTIS no. PB 193 487, $3.00)
BRH/DEP 70-22	Report of Tests for X-ray Emission from a Kayotron Electrostatic Generator and Particle Accelerator (August 1970) (NTIS no. PB 193 522, $3.00)

(continued on inside of back cover)

DHEW Publication No. (FDA) 72-8020
BRH DEP 72-6

EVALUATION of the S. S. WHITE PANOREX® X-RAY MACHINE

Arnold F. Jacobson
John P. Ferguson

X-ray Exposure Control Labaratory
Division of Electronic Products

December 1971

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
FOOD AND DRUG ADMINISTRATION
Bureau of Radiological Health
Rockville, Maryland 20852

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price 65 cents

The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health, Education, and Welfare or the Public Health Service.

FOREWORD

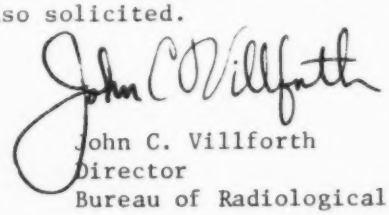
The Bureau of Radiological Health continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in appropriate scientific journals and technical report and technical note series for the Bureau's divisions, offices, and laboratories.

The technical reports and notes of the Division of Electronic Products allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports and notes are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. They are also included in the collections of the Library of Congress and the National Technical Information Service.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.



John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The Radiation Control for Health and Safety Act of 1968 provides for the establishment of an electronic product radiation control program which includes the development and administration of performance standards to control the emission of electronic product radiation. Performance standards have recently been developed for diagnostic x-ray equipment used by practitioners of the healing arts. To develop appropriate standards for unique x-ray apparatus, such as the S. S. White Panorex®, typical operational data must first be obtained.

This report reflects the efforts of the Division of Electronic Products (DEP) to keep informed of new and unusual types of commercial x-ray equipment and to gather information related to operating characteristics and radiation exposure in the use of such equipment. It describes the procedures and results of tests made to determine physical and operating characteristics of the Panorex x-ray machine and presents recommendations based on the data obtained. Results of a study of phantom and patient exposures involved in the clinical use of the Panorex will be published as a separate DEP report in this series.

Robert L. Elder, Sc.D.
Director
Division of Electronic Products

Preceding page blank

CONTENTS

	Page
FOREWORD	iii
PREFACE	v
FIGURES	ix
ABSTRACT	xi
1. INTRODUCTION	1
2. DESCRIPTION OF THE PANOREX UNIT	
2.1 THE LAMINOGRAPHIC TECHNIQUE	3
2.2 SPECIFICATIONS AND CONTROLS	8
2.2.1 Main Line Switch	8
2.2.2 Radiation Switch	8
2.2.3 Directional Switch	8
2.2.4 Milliampere Control	8
2.2.5 Kilovolt Control	10
2.3 OPERATING PROCEDURE	10
2.4 SPACE REQUIREMENTS	10
3. PRELIMINARY TEST PROCEDURES	11
3.1 EQUIPMENT ALTERATIONS	11
3.2 PRIMARY VOLTAGES	11
4. kVp TESTS	12
4.1 kVp METER CALIBRATION	12
4.2 kVp VARIATION WITH LINE VOLTAGE	12
5. mA TESTS	17
6. HALF-VALUE LAYER AND FILTRATION	18
7. FOCAL SPOT	20
7.1 FOCAL SPOT DEPTH	20
7.2 FOCAL SPOT SIZE	20
8. X-RAY BEAM TESTS	24
8.1 BEAM ALIGNMENT.	24
8.2 DIMENSIONS OF THE X-RAY BEAM	26

Preceding page blank

		Page
9.	EXCURSION TIME AND EXPOSURE REPRODUCIBILITY	28
	9.1 X-RAY ON TIME	28
	9.2 EXPOSURE REPRODUCIBILITY	29
10.	STRAY RADIATION	31
11.	DETERMINATION OF BEAM QUALITY AND FILTRATION	38
12.	OPERATIONAL OBSERVATIONS AND COMMENTS	41
13.	CONCLUSIONS AND RECOMMENDATIONS	43
	13.1 RECOMMENDATIONS TO THE MANUFACTURER	43
	13.2 RECOMMENDED SURVEY TECHNIQUES	44
REFERENCES		45
APPENDIX A -	MANUFACTURER'S SPECIFICATIONS FOR THE PANOREX X-RAY MACHINE	47
APPENDIX B -	PANOREX OPERATING PROCEDURE	51

FIGURES

		Page
Figure 1.	Panorex x-ray machine	2
Figure 2.	Laminography: object lying in plane of projection	4
Figure 3.	Laminography: object outside plane of projection	4
Figure 4.	Panorex equipment	5
Figure 5.	Panorex radiography: schematic drawings of half-cycle exposure	6
Figure 6.	Typical Panorex radiograph	7
Figure 7.	Panorex control cabinet	9
Figure 8.	Space requirements of the Panorex	10
Figure 9.	kVp calibration	13
Figure 10.	Variation of indicated kVp with line voltage	15
Figure 11.	Variation of kVp calibration with line voltage	16
Figure 12.	Half-value layer apparatus	18
Figure 13.	Focal spot depth measurement arrangement	21
Figure 14.	Focal spot size measurement arrangement	22
Figure 15.	Image of the focal spot	23
Figure 16.	Representation of x-ray beam alignment procedure	25
Figure 17.	X-ray beam image at the cassette holder	26
Figure 18.	Phantom positioned in the Panorex	32
Figure 19.	Arrangement of thermoluminescent dosimeters around phantom	33
Figure 20.	Stray radiation isoexposure curves: mR per excursion at 90 kVp	34
Figure 21.	Leakage radiation at 1.5 inches below x-ray beam isoexposure curves: mR per excursion at 90 kVp.	36
Figure 22.	Scattered radiation isoexposure curves: mR per excursion at 90 kVp	37

ABSTRACT

An evaluation of the S. S. White Panorex® dental x-ray machine was performed. The physical and operational characteristics of the unit were investigated with particular emphasis on kVp and mA meter calibrations, focal spot characteristics, x-ray beam dimensions, half-value layers, and inherent filtration. Isoexposure curves for radiation in the vicinity of a phantom were determined, and survey techniques for half-value layer measurements and x-ray beam alignment were investigated. Recommendations based on the observed operation of the Panorex are advanced.

Preceding page blank

EVALUATION OF THE
S. S. WHITE PANOREX® X-RAY MACHINE

1. INTRODUCTION

In recent years the use of panoramic dental radiography, both as a clinical procedure and as a means of large-scale patient screening, has been increasing. This procedure provides a full-mouth radiograph in which anatomic spatial relationships are maintained in a single exposure, thus providing a wider field of view than conventional techniques. To supply needed operational data for panoramic units, the S. S. White Panorex® unit (fig.1), which employs the technique of laminography, was tested and evaluated.

This study had two main objectives. The first was to gather data on the operational characteristics of the Panorex as well as on the radiation exposures associated with its use. The second was to formulate suitable survey techniques for the Panorex, whose unique nature has occasionally posed difficulties for radiation protection surveyors, and to make recommendations based on the relative merits of these techniques.

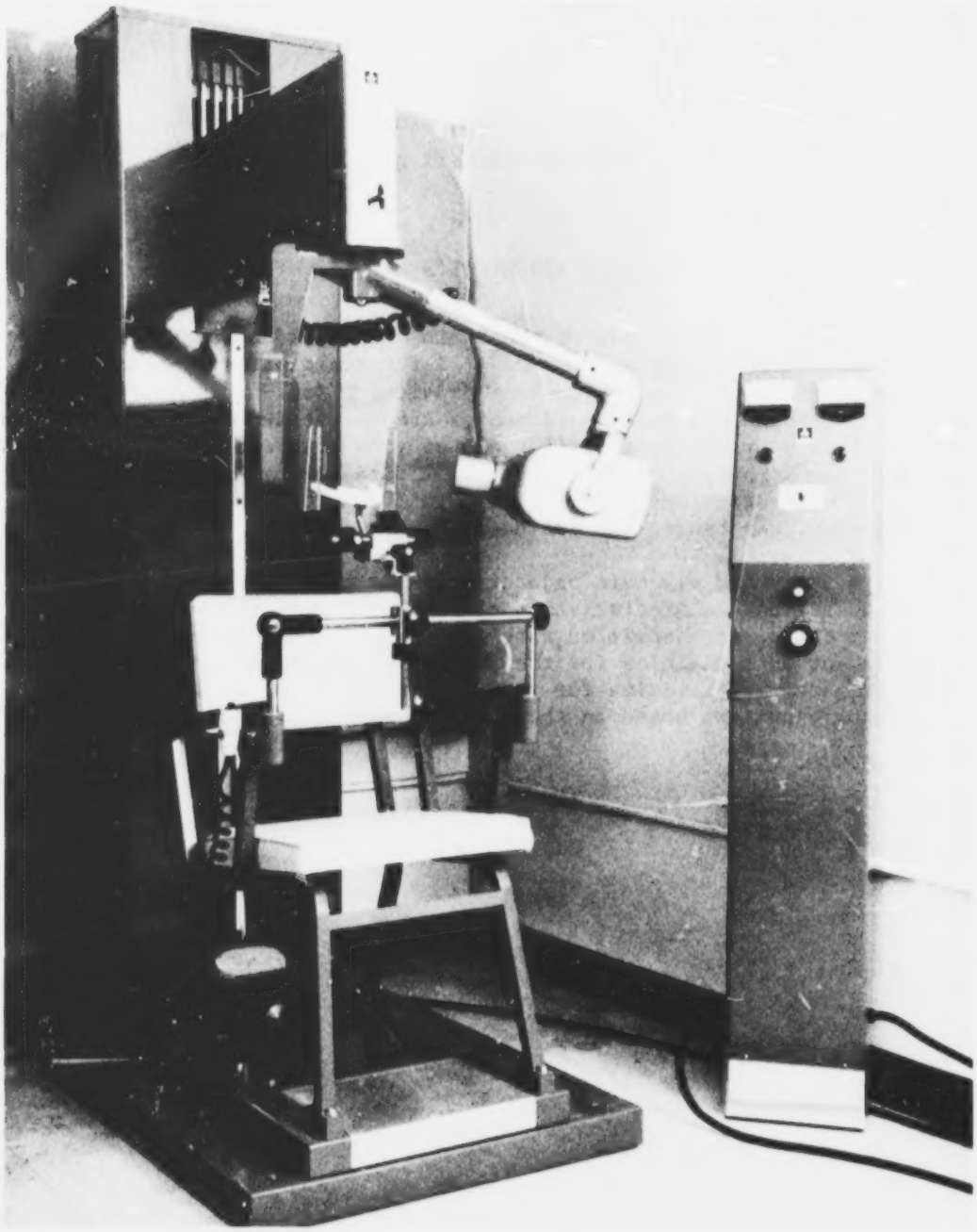


Figure 1. Panorex x-ray machine.

2. DESCRIPTION OF THE PANOREX UNIT

2.1 THE LAMINOGRAPHIC TECHNIQUE

Laminography is a technique for radiography of plane sections in solid objects. This technique involves the movement of the x-ray source in one direction and the film in the opposite direction about the object to be radiographed. The images of a structure in the plane being visualized all appear at the same place on the film, producing a single clear image (fig. 2). Images of objects in planes other than the plane of projection move relative to the center of the film and, therefore, are blurred (fig. 3). The technique was applied to dental radiography more than 20 years ago by Paatero *(1)*.

The Panorex, which resulted from the research of Hudson, Kumpula, and Dickson *(2)*, utilizes the principle of curved-surface laminography. A flat cassette carrier for the film and a narrow-beam x-ray source are mounted on opposite ends of a horizontal arm. The arm rotates and carries the film and source around the patient's head which is held stationary by a cephalostat. The cassette carrier, tubehead, and head positioner are shown in figure 4. The movement of the x-ray source and the film is synchronized by a cam shaped to the outline of the dental arch.

Two centers of rotation are used during a panoramic exposure. One side of the face is first exposed from one center of rotation. Then, midway through the cycle, the axis of rotation is changed by an automatic lateral shift of the chair, and the other side of the face is exposed. A portion of the rotation sequence is illustrated in figure 5. During the 2-second interval of the chair shift, the x-ray tube is deenergized. The entire procedure requires 22 seconds. The result is a panoramic radiograph of the entire dentoalveolar region on a single film, as shown in figure 6. Recorded on the film are the right and left halves of the dental arch plus a duplication of the left and right central incisors.

The panoramic technique does not necessarily eliminate the need for conventional dental radiographs. "The panoramic technique is useful for a survey type of examination, but it suffers from distortion and lack of detail. Consequently, panoramic radiographs do not eliminate a residual need for radiographs obtained from regular equipment"*(5)*.

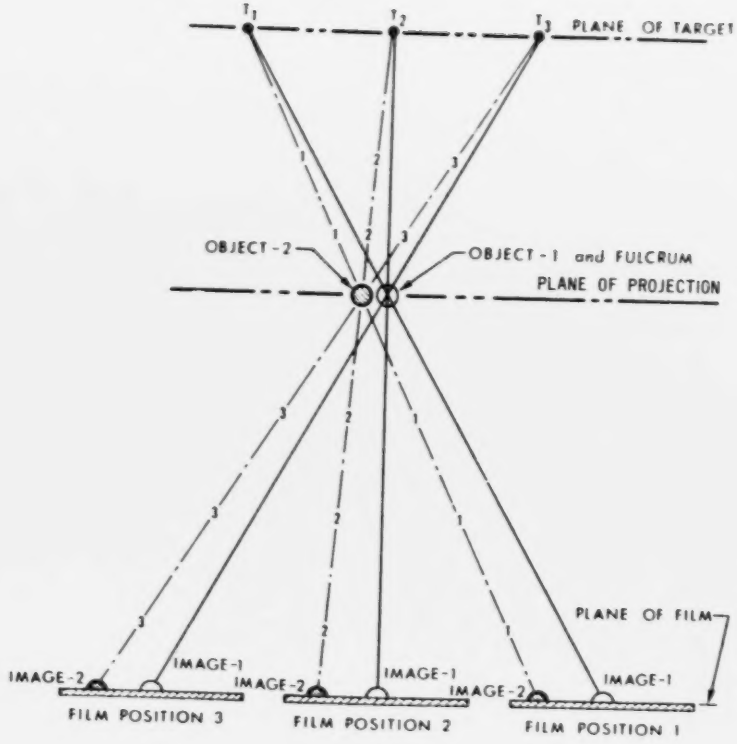


Figure 2. Laminography: object lying in plane of projection *(3)*. (Reproduced with permission from Postgraduate Medicine[C], McGraw-Hill, Inc.)

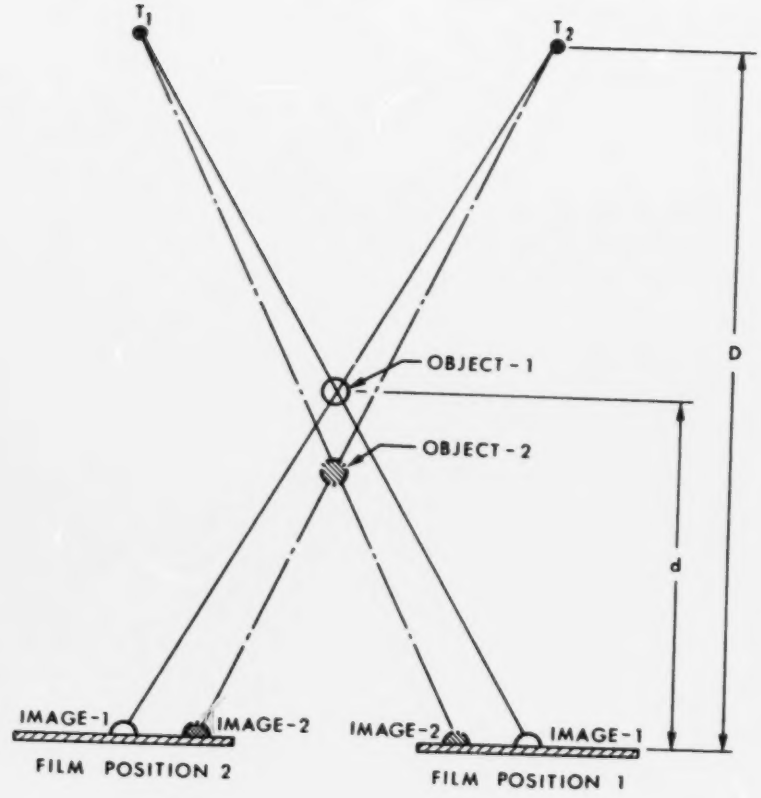
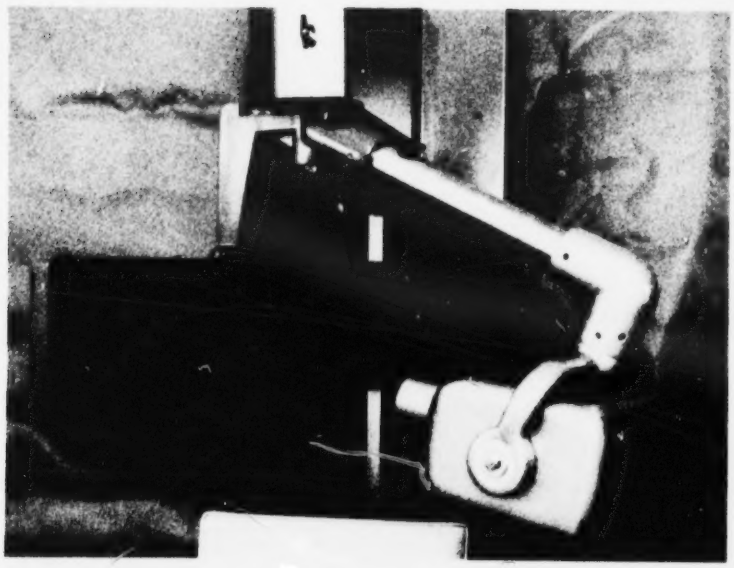
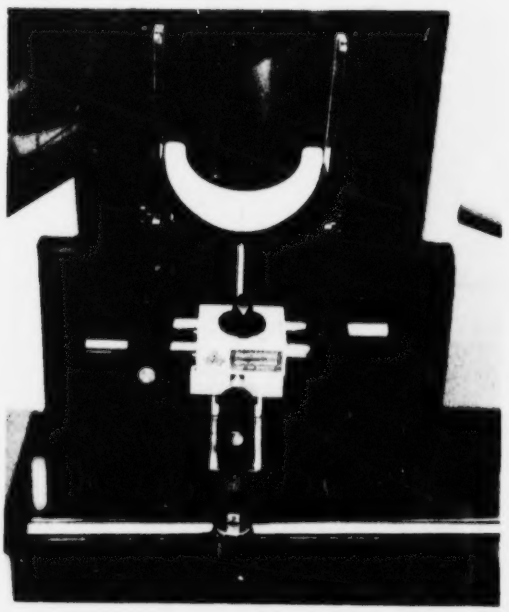


Figure 3. Laminography: object outside plane of projection *(3)*. (Reproduced with permission from Postgraduate Medicine[C], McGraw-Hill, Inc.)



a. Cassette carrier and tubehead.

b. Tubehead.



c. Pancentric head positioner (cephalostat).

Figure 4. Panorex equipment.

Figure 5. Panorex radiography: schematic drawings of half-cycle exposure *(4)*. (Reprinted from Kodak Dental Radiography and Photography with permission from W. D. Updegrave, D.D.S.)

NOT REPRODUCIBLE

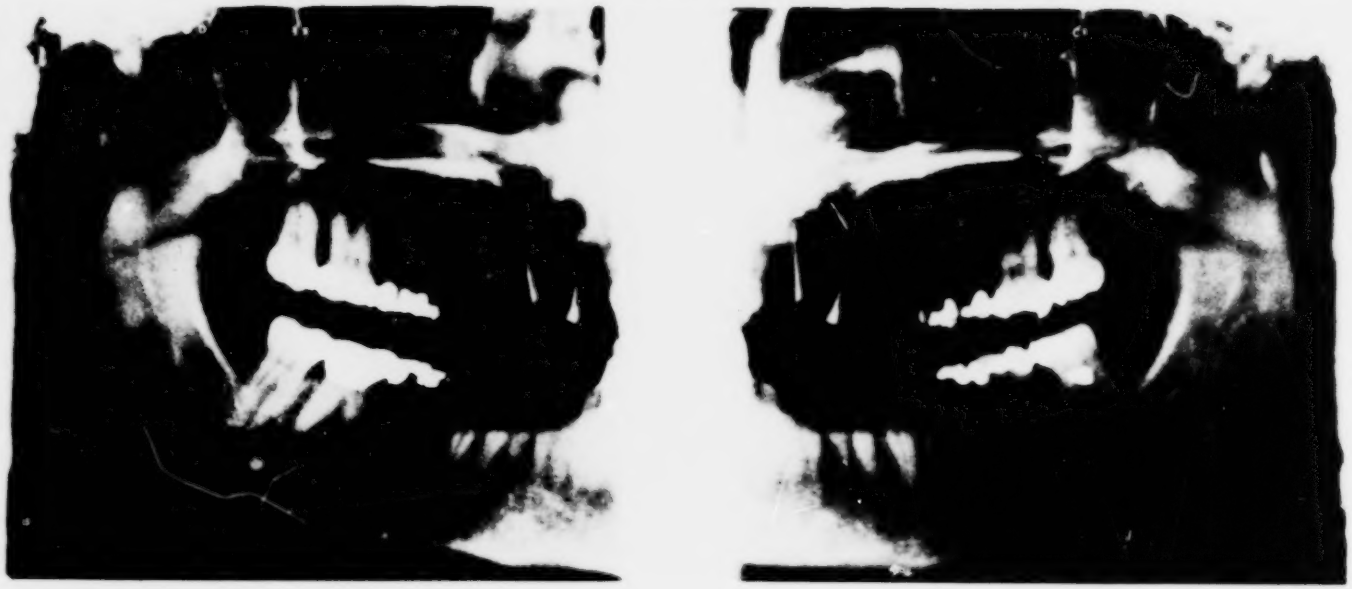


Figure 6. Typical Panorex radiograph. (Reproduced with permission from S. S. White Co.)

2.2 SPECIFICATIONS AND CONTROLS

The manufacturer's specifications for the Panorex are listed in appendix A. The various controls and associated hardware are described below.

2.2.1 Main Line Switch

A toggle power switch is located on the upper left side of the control cabinet (fig. 7B). When it is in the "on" position, a green pilot light on the face of the control unit lights up.

2.2.2 Radiation Switch

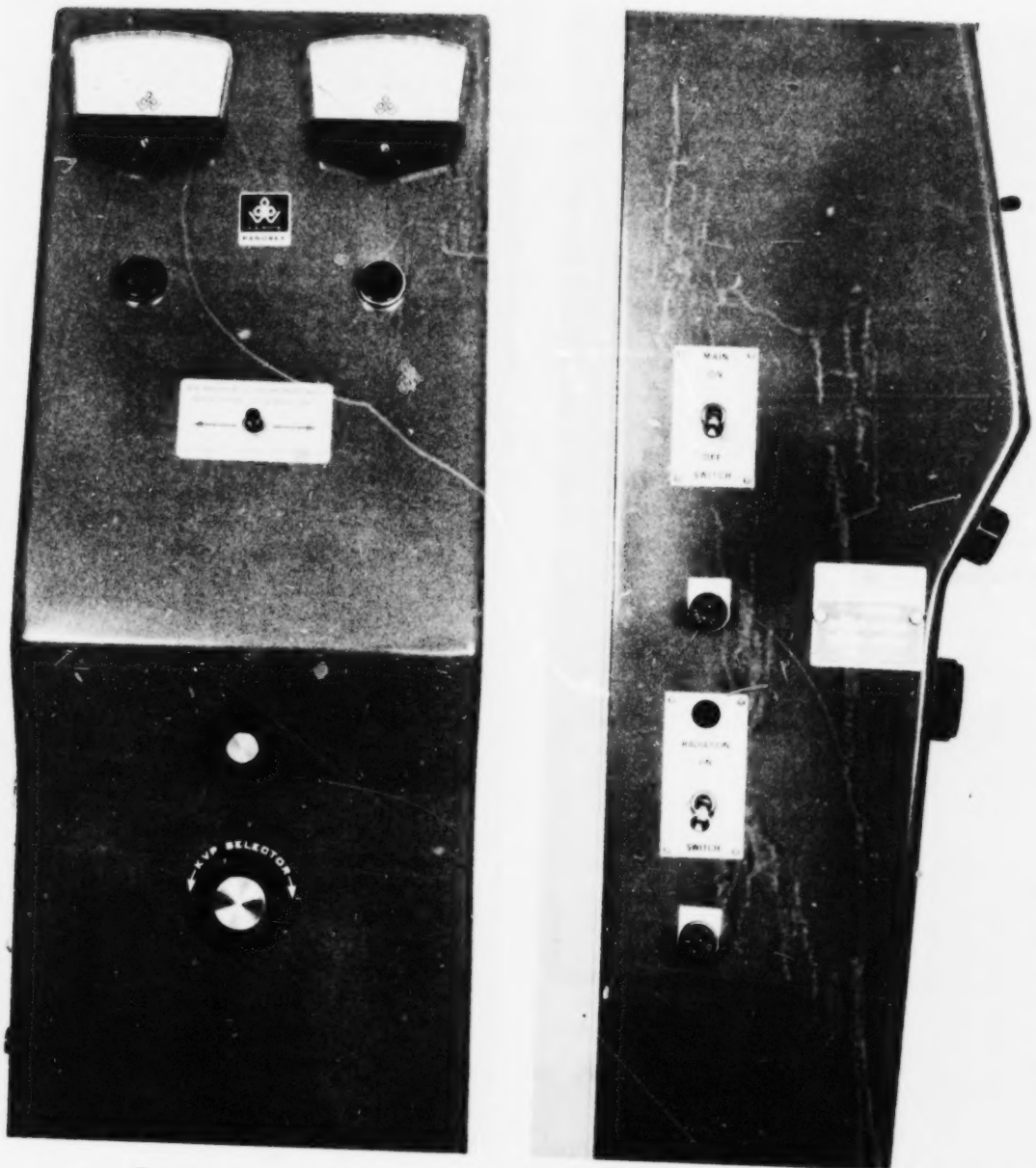
The radiation switch is located on the lower left side of the control cabinet (fig. 7b). When it is in the "on" position, a red pilot light directly above the radiation switch lights up to indicate that radiation will be produced during an excursion of the tubehead and cassette holder.

2.2.3 Directional Switch

The directional switch is located at the center of the face of the control cabinet (fig. 7a) and can be pushed to the left or right side. Its function is to initiate the excursion of the tubehead and cassette holder. When the radiation switch is in the "on" position and the directional switch is pushed, a red pilot light (labeled "x-ray") on the face of the control unit lights up and a Panorex exposure will be obtained. When the excursion is completed, the unit automatically stops rotation and x-ray production ceases. The directional switch is a "dead-man" type which requires continuous pressure to maintain the rotation of the tubehead and cassette holder. Therefore, it is possible to terminate the exposure whenever it is deemed necessary before the full excursion is completed. If the excursion is interrupted by the operator at any point, it can continue only in the same direction unless the main switch is turned off and back on again. This feature is designed into the operation of the Panorex so that the direction of the excursion will always be in phase with the direction of the chair shift. Two metallic plates are positioned on the base of the Panorex stating, "When this is visible, tubehead should be located directly above. If not, the chair is out of phase." Consequently, the operator can determine by observation whether the movement of the tube and the shift of the chair are in phase. The Panorex will not operate unless the directional switch is pushed in the proper direction.

2.2.4 Milliampere Control

The mA control is located below the directional switch. The mA can be varied continuously from 0 to 14 mA, as indicated by the meter located at the top right-hand side of the control cabinet. A setting between 5 and 13 mA is usually selected. The mA can be read only during a rotational cycle. A time period of approximately 1.5 seconds is allotted for this adjustment at the beginning of the exposure cycle.



a. Front view

b. Side view

Figure 7. Panorex control cabinet.

2.2.5 Kilovolt Control

The kVp control is located below the mA control. The peak tube potential is continuously variable from 50 to 90 peak kilovolts and can be preread and adjusted once the main switch is turned on. The kVp meter located at the top left-hand side of the control cabinet indicates the selected setting.

2.3 OPERATING PROCEDURE

A detailed description of the operating procedures recommended in the Panorex operator's manual *(6)* is presented in appendix B. A technique chart for the Panorex is also included in this appendix.

2.4 SPACE REQUIREMENTS

The Panorex requires an overall working space of approximately 8 feet by 4 feet. The space requirements are illustrated in figure 8.

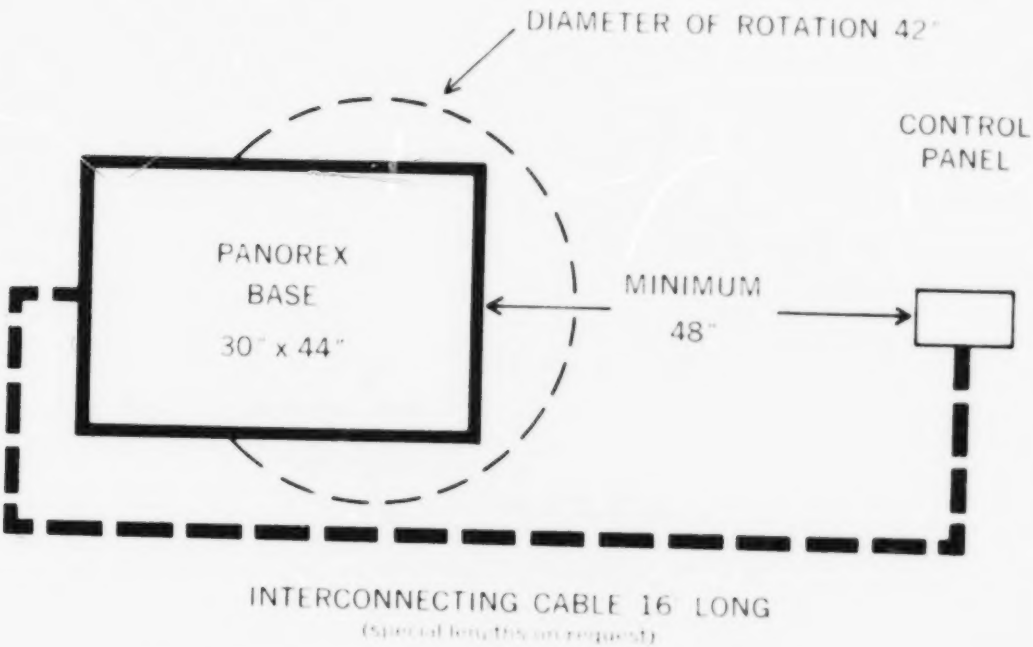


Figure 8. Space requirements of the Panorex *(6)*.
(Reprinted with permission from S.S. White Company)

3. PRELIMINARY TEST PROCEDURES

3.1 EQUIPMENT ALTERATIONS

In order to facilitate the performance of tests of the physical and operational characteristics of the Panorex, several preliminary steps were taken. The tubehead excursion motor was disconnected to prevent rotary motion and to allow the execution of stationary exposures. In addition, the lead collimator was removed from the tubehead and the cassette holder was detached from its arm to provide unobstructed access to the full radiation beam.

3.2 PRIMARY VOLTAGES

The Panorex requires line voltage in the range of 100 to 130 volts. It has provisions for two different line voltage connections: 120 volts or less and over 120 volts. The manufacturer states that if the line voltage is over 120 volts, the wire ordinarily fastened to terminal #1 of the terminal panel at the rear of the kVp selector should be transferred to terminal #2. Since the unit was received wired for 120 volts or less, the line voltage was set and maintained at 115 volts by a General Radio-Type 1570-A automatic voltage regulator throughout these tests, except where noted. A Weston Model 904 AC voltmeter was connected across the output terminals of the voltage regulator to monitor the voltage supplied to the Panorex.

4. kVp TESTS

4.1 kVp METER CALIBRATION

The accuracy of the kVp meter was determined by the characteristic x-ray spectrometry method. In this technique an x-ray spectrometer consisting of a multichannel analyzer and a Li(Ge) detector is used to determine the minimum indicated kilovoltage at which the energy of the radiation produced using the x-ray high-voltage generator under test exceeds the known k-shell absorption edge of a target material and causes characteristic k-shell x-ray emission. At this indicated kilovoltage the peak potential on the x-ray tube is numerically equal to the energy of the absorption edge. Use of the spectrometer enables differentiation between characteristic k-shell x rays and x rays of other energies.

Radiators with k-shell absorption edges between 45 and 90 keV were chosen to cover the entire kVp meter range of the Panorex. Measurements were made at 5, 10, and 14 mA to determine the effect of tube current upon kVp meter calibration. Calibration curves were plotted as indicated kVp versus measured kVp (fig. 9). All three curves were approximately 45-degree straight lines. The error increased with mA and ranged from 3 kVp at 5 mA to 13 kVp at 14 mA. The data are shown in table 1.

4.2 kVp VARIATION WITH LINE VOLTAGE

Some variation in kVp is to be expected with variations in line voltage at a given setting of the kVp control. The kVp meter indication was observed at several line voltages. For line voltages greater than 120 volts, the wiring change described in paragraph 3.2 was made. The results were plotted as indicated kVp versus line voltage for five positions of the kVp control knob (fig. 10).

To ascertain whether changes in line voltage affect the kVp meter calibration, the procedure described in paragraph 4.1 was repeated at 10 mA at several line voltages. Calibration curves (fig. 11) were plotted as described previously. It should be noted that there was a sharp demarcation between the results below and above 120 volts, the latter exhibiting trends similar to those of the 100- to 120-volt range. In general, within the two ranges, the kVp meter readings increased and the difference between indicated and measured kVp decreased with increasing line voltage.

Unless otherwise stated, the indicated rather than the measured kVp is used throughout this report.

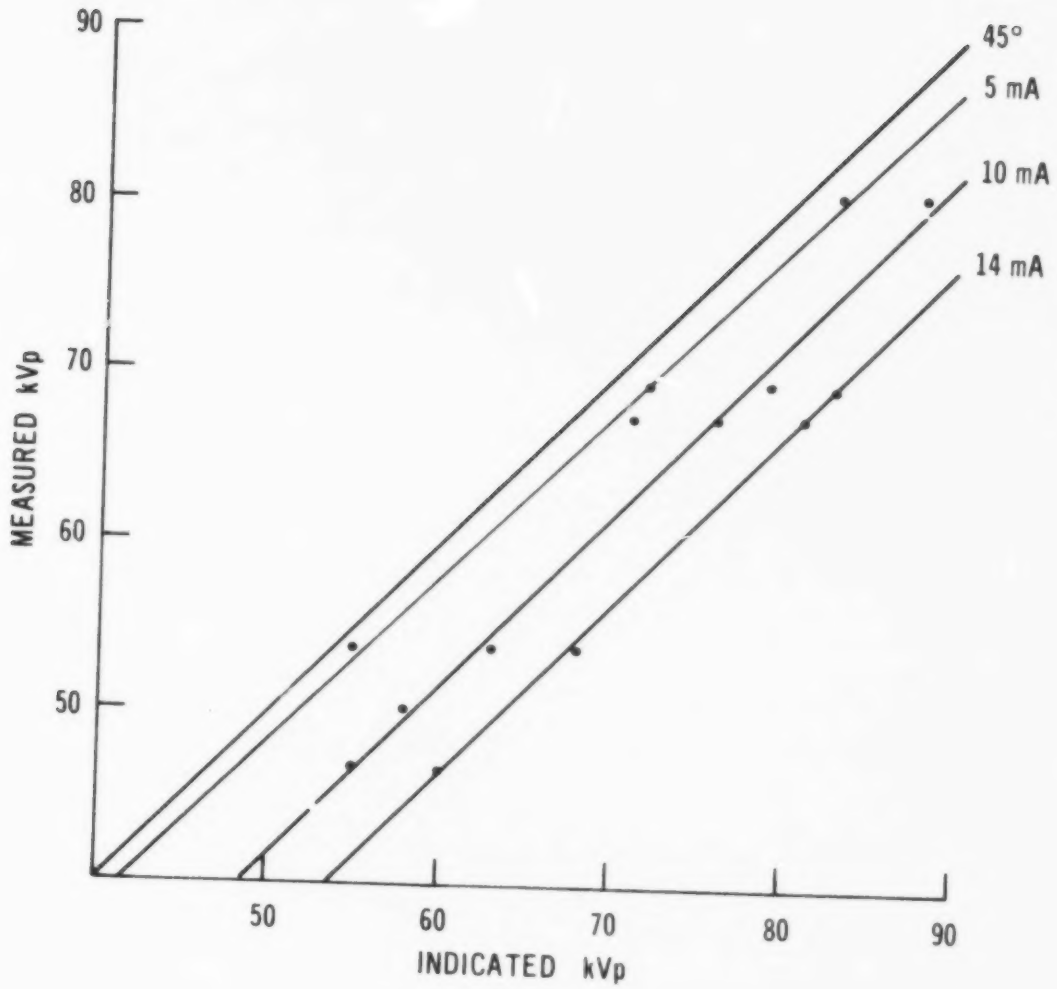


Figure 9. kVp calibration.

Table 1. kVp calibration data.

Line voltage	mA	kVp meter indication	Measured kVp
115	5	55	53.8
		71	67.4
		72	69.5
		83	80.7
	10	55	46.8
		58	50.2
		63	53.8
		76	67.4
		79	69.5
		88	80.7
	14	60	46.8
		68	53.8
		81	67.4
		83	69.5
110	10	57	46.8
		65	53.8
		80	69.5
120	10	53	46.8
		60	53.8
		77	69.5
		86	80.7
125	10	60	46.8
		69	53.8
		83	69.5

Radiators	keV
Sm	46.8
Gd	50.2
Dy	53.8
Ta	67.4
W	69.5
Au	80.7

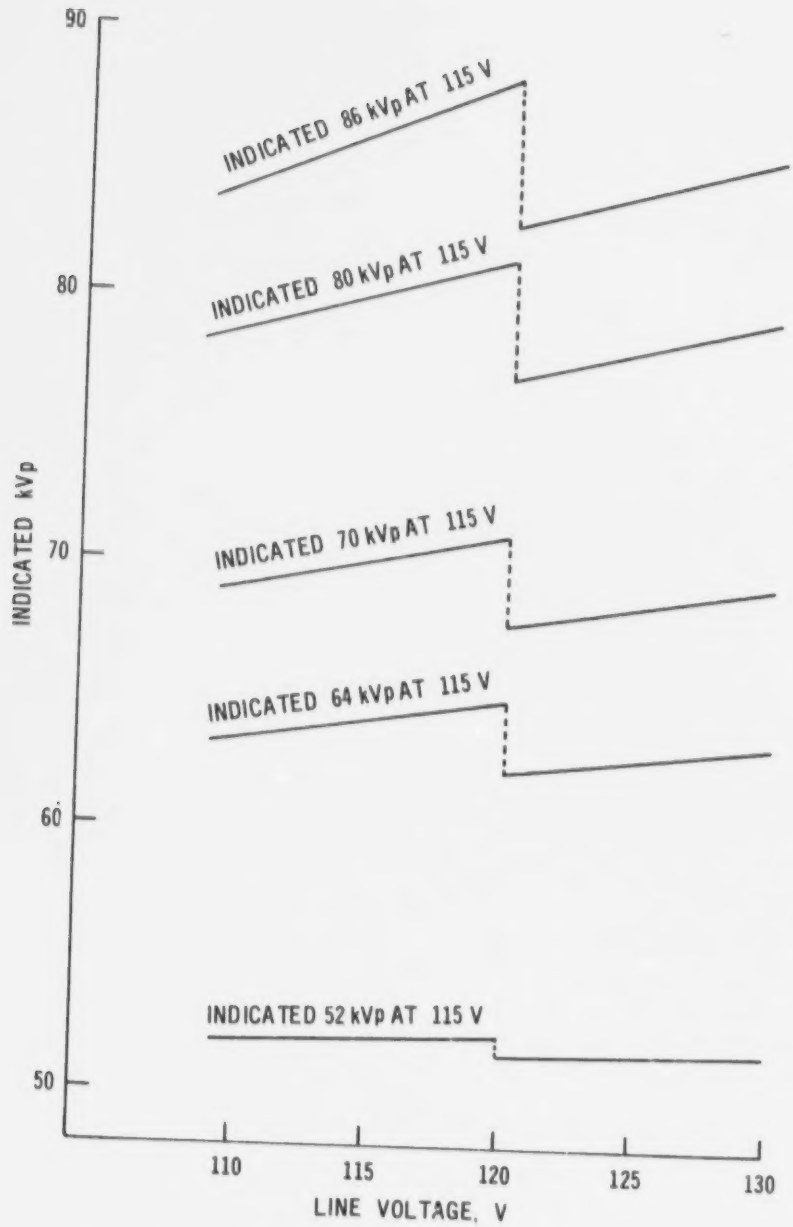


Figure 10. Variation of indicated kVp with line voltage.

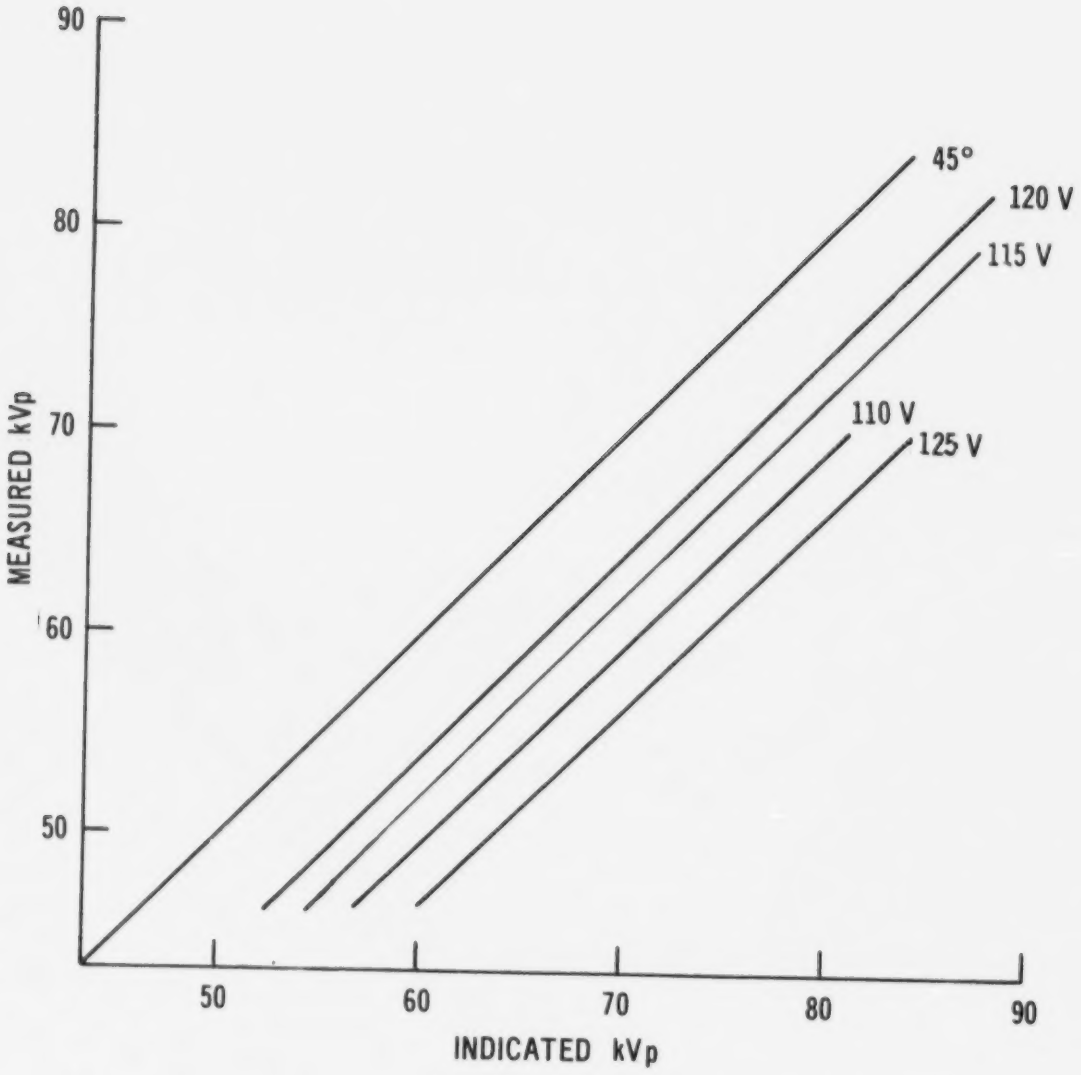


Figure 11. Variation of kVp calibration with line voltage.

5. mA TESTS

Since the high-voltage transformer was enclosed by the x-ray tube housing, the accuracy of the panel mA meter was determined by connecting a calibrated Westinghouse Type PX-161 DC milliammeter in series with it. Exposures were made, and the readings of the two meters recorded. Very good agreement was observed, as exhibited in table 2.

Unless otherwise stated, the indicated mA is used throughout this report.

Table 2. mA calibration

kVp	mA meter indication	Measured mA
52	5.0	5.1
	10.0	10.0
	14.0	14.0
90	5.0	5.1
	10.0	10.0
	14.0	14.0

6. HALF-VALUE LAYER AND FILTRATION

The half-value layer was measured by using the apparatus diagrammed in figure 12. "A" and "B" were lead sheets with 1/2-inch and 1-inch apertures, respectively. The aluminum absorbers used were type 1100 alloy. A Victoreen 555 dosemeter with a Model 1DA ion chamber probe was used as the radiation detector. The detector was positioned with its long axis parallel to the central ray and so aligned that it was completely covered by the beam. Replicate measurements were made at the maximum indicated kilovoltage, 90 kVp, and 10 mA. An attenuation curve was plotted and used to determine the half-value layer, which was found to be 1.90 mm Al. As "good geometry" conditions were considered to exist in the experimental setup, this result was accepted as a reasonable approximation of the unique half-value layer *(7)*.

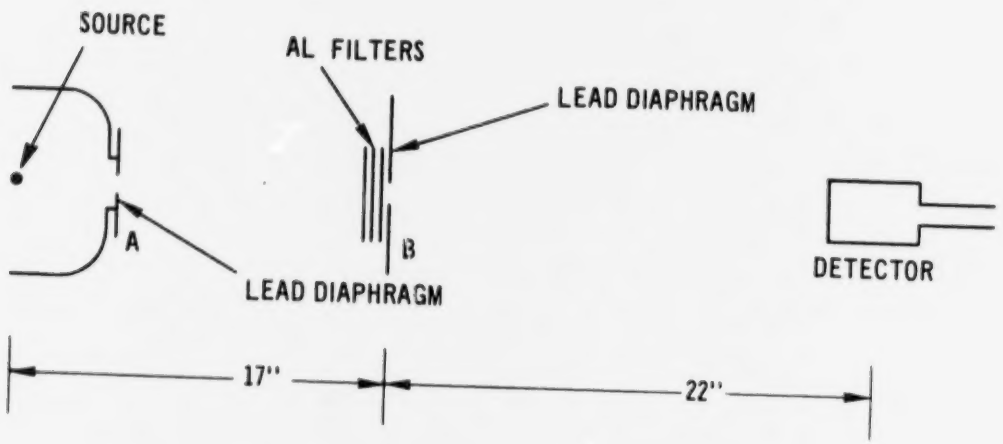


Figure 12. Half-value layer apparatus.

The total filtration of the Panorex was determined by comparing the attenuation curve described above with one produced by a self-rectified, beryllium-window GE Maximar 100 x-ray unit under the same experimental conditions and at the same "true"[1] kVp. By matching the Panorex attenuation curve with the appropriate section of the Maximar reference curve, the point on the reference curve corresponding to zero absorber thickness on the Panorex curve was determined as the total filtration of the Panorex.

The thickness of the added aluminum filtration in the Panorex was measured and found to be 0.52 mm. This amount was subtracted from the total filtration value to yield a value for the inherent filtration. The filtration results shown in table 3 indicate that the unit tested contained less than the recommended 2.5 mm aluminum total filtration *(8)*.

[1] As determined from kVp calibration curves.

Table 3. Total and inherent filtration (mm Al).

Indicated kVp:	90
"True" kVp:	82
Half-value layer:	1.90 mm Al
Total filtration:	1.83 mm Al
Inherent filtration:	1.31 mm Al

7. FOCAL SPOT

7.1 FOCAL SPOT DEPTH

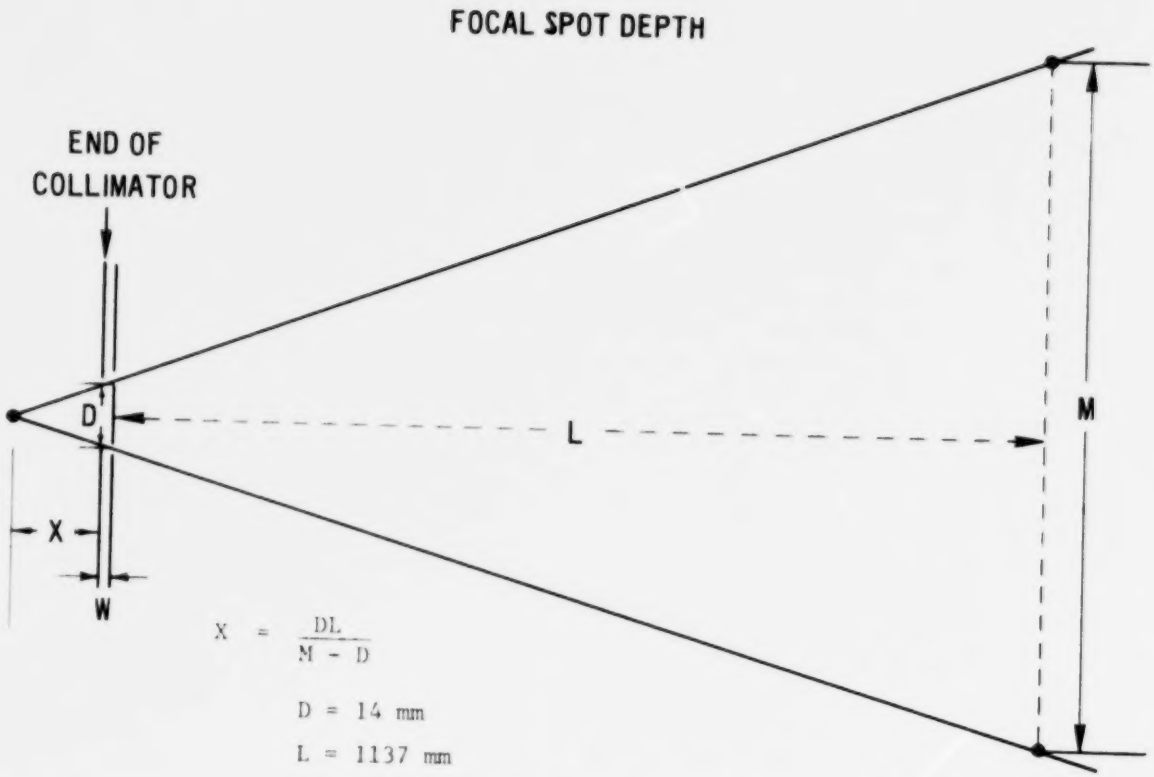
To determine the position of the focal spot, the technique of dual-pinhole radiography was employed. Dual radiographic images of the focal spot are produced by the pinholes, and the focal spot depth can be calculated by measuring the distance between the images, between the pinholes, and between the plane of the pinholes and the film.

With the Panorex collimator in position, a piece of lead containing two 0.35-mm-diameter (#80 wire drill) pinholes, 14 mm apart, was placed over the slit. A sheet of Kodak Type M film was positioned a known distance from the pinholes, and an exposure was made. The distance between the radiographic images was then measured, and the resulting data were used to calculate the focal spot depth. The measurement and calculation techniques are illustrated in figure 13. The calculated value of 4.98 inches was in good agreement with the manufacturer's specified distance of 5 inches between the focal spot and the end of the collimator.

7.2 FOCAL SPOT SIZE

With the collimator removed, a standard pinhole of 0.030 diameter *(9)* and a sheet of Kodak Type M film were positioned in line with the tubehead exit port at the distances shown in figure 14. The resulting radiographic image of the focal spot is shown in figure 15.

According to the manufacturer's specifications, the Panorex focal spot size is 0.8-mm square. The magnification factor was 2.46, and the width of the image was measured as 2.0 mm, yielding a calculated value for the focal spot width of about 0.8 mm. The height of the image was 3.6 mm, which corresponds to a focal spot height of 1.4 mm. For line-focus tubes, however, NBS Handbook 89 *(9)* recommends that this value be further corrected by a multiplier of 0.7 to allow for the lengthwise distribution of energy in the focal spot. Thus, the height of the focal spot was determined to be 1.0 mm. These values cannot be considered as absolutely accurate measures of the focal spot size because of the distortion in the photographic image and the difficulty in measuring it accurately. Nevertheless, within the limitations of pinhole alignment with the focal spot and dimension measurement uncertainties, the size appears to be on the order of that claimed by the manufacturer.



$$X = \frac{DL}{M - D}$$

D = 14 mm

L = 1137 mm

M = 138 mm

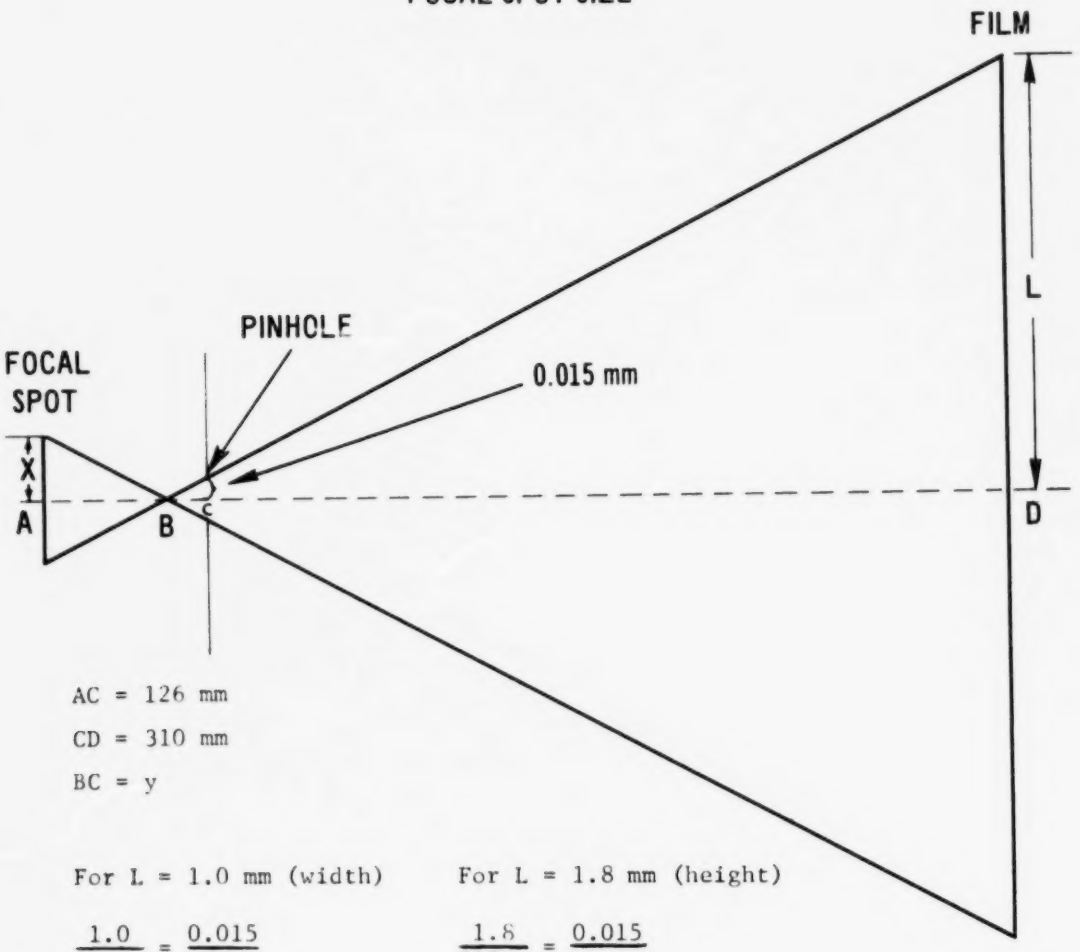
w = 2 mm

$$X = \frac{14 \times 1137}{138 - 14} - 2$$

X = 126 mm = 4.98 in

Figure 13. Focal spot depth measurement arrangement.

FOCAL SPOT SIZE



AC = 126 mm

CD = 310 mm

BC = y

For L = 1.0 mm (width)

$$\frac{1.0}{310+y} = \frac{0.015}{y}$$

$$y = 4.65 \text{ mm}$$

$$\frac{x}{126-y} = \frac{0.015}{4.65}$$

$$x = 0.39 \text{ mm}$$

$$d = 2x = 0.78 \text{ mm}$$

For L = 1.8 mm (height)

$$\frac{1.8}{310+y} = \frac{0.015}{y}$$

$$y = 2.58 \text{ mm}$$

$$\frac{x}{126-y} = \frac{0.015}{2.58}$$

$$x = 0.72 \text{ mm}$$

$$d = 2x = 1.44 \text{ mm}$$

Figure 14. Focal spot size measurement arrangement.

Figure 15. Image of the focal spot.

8. X-RAY BEAM TESTS

8.1 BEAM ALIGNMENT

Upon replacing the collimator on the tubehead, it was deemed necessary to check the alignment of the x-ray beam and the slot in the cassette holder. Instructions for this procedure are provided in the Panorex Installation and Service Manual. The first step described, loosening the flexible coupling to allow the tubehead and cassette holder assembly to remain stationary, had already been done. The suggested procedure is then to attach a small fluoroscopic screen to the end of a ruler or other long object, hold the screen in front of the slot at the cassette holder face, make an exposure (70 kVp, 5 mA), and if the field is not contained within the area of the slot, make appropriate adjustments.

This procedure was found to be somewhat impractical, as it was difficult to ascertain the precise spatial relationship between the image on the fluorescent screen and the slot in the cassette holder when the screen was held as described. Hence, an alternate procedure was formulated.

A ruler and a pencil were used to draw vertical lines extending the upper and lower edges of the slot. A 5-inch fluorescent screen was taped to the cassette holder so that it covered the slot, and its bottom edge was lined up with the bottom edge of the slot. The lines previously drawn were then connected across the screen, thus defining the horizontal dimensions of the slot, and a small fluorescent strip was taped at the bottom edge of the screen below the slot to aid in describing its lower edge. This setup is illustrated in figure 16.

The room was darkered and an exposure made. The fluorescent screen was then illuminated with a dim red light, and the spatial relationship between the beam and the slot as outlined on the screen became immediately apparent. If the beam crossed the slot at an angle, the cone was rotated until the slit and the slot were parallel. If it was located to the left or right of the slot, the tubehead was rotated accordingly. If the beam either illuminated the fluorescent strip below the slot or did not extend to the bottom of the screen, the tubehead was rotated vertically until the bottom edge of the beam just coincided with the bottom edge of the screen without illuminating the strip. This completed the alignment of the x-ray beam.

The complete directions for altering the position of the cone and the tubehead in order to align the beam may be found on page 8 of the Panorex Installation and Service Manual *(10)*.

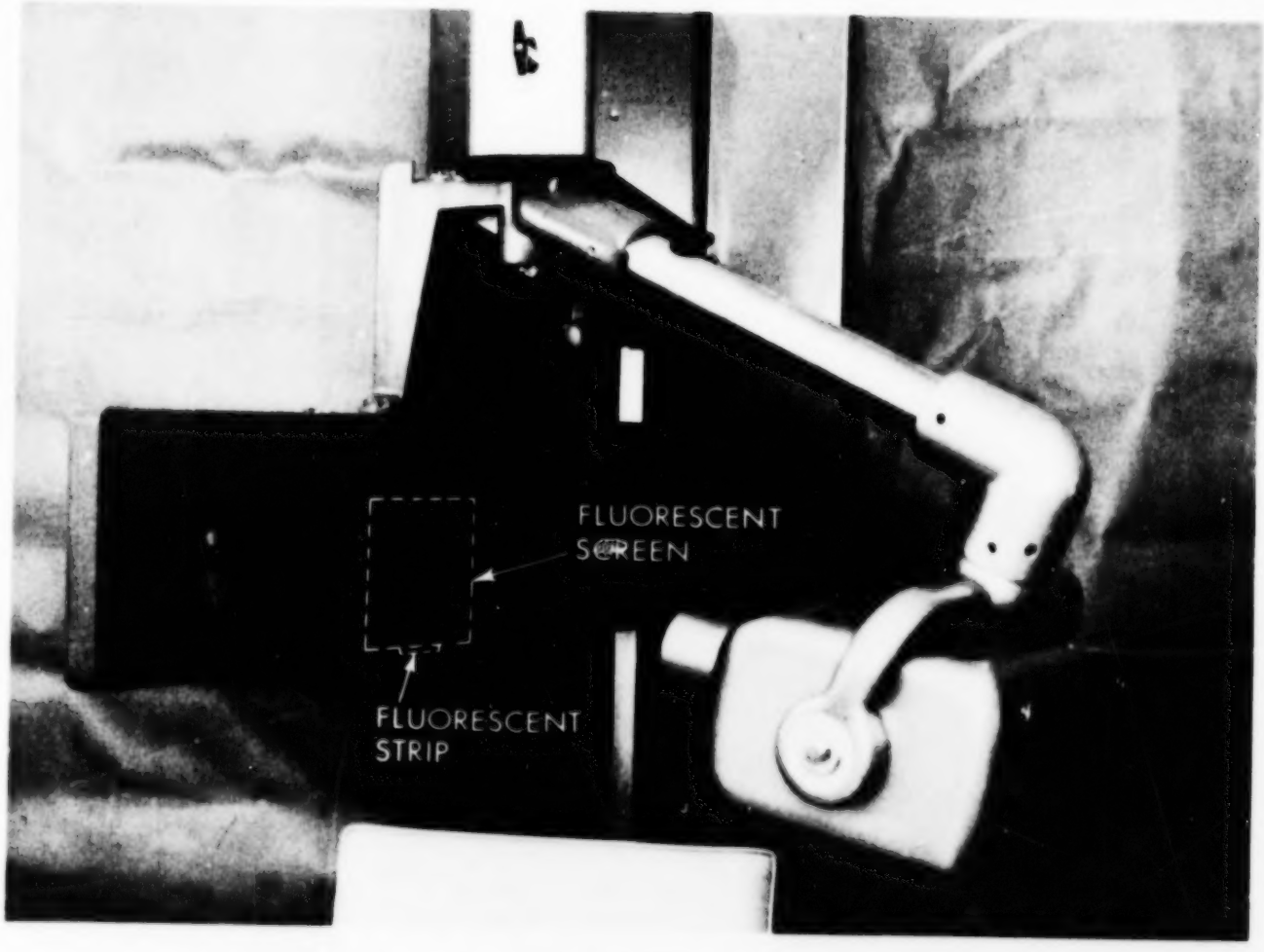


Figure 16. Representation of x-ray beam alignment procedure.

8.2 DIMENSIONS OF THE X-RAY BEAM

The manufacturer states that the dimensions of the x-ray beam do not exceed those of the slot in the cassette holder through which it passes. In order to check this, a sheet of Kodak Royal Blue x-ray film was attached to the front of the cassette holder, and an exposure of 0.5 mAs was made at 90 kVp. The image obtained is shown in figure 17.

Figure 17. X-ray beam image at the cassette holder.

The edge of the x-ray beam was defined as the locus of points at which the radiation intensity was 1/10 the intensity at the center of the beam. To locate the edge, the film mentioned above was scanned by a densitometer and the density profile of the x-ray beam was plotted on an x-y recorder. The net density at the center was 1.2. The exposure and net density of Kodak Royal Blue x-ray film are linearly related up to net densities of 1.2 when the film is exposed directly to x rays. Therefore, it was possible to read 1/10 the exposure at the center of the beam directly from the density plot. Once the edges of the beam were located by this procedure, the beam dimensions were readily measured. The results are shown in table 3.

Table 3. Dimensions of the x-ray beam.

Dimension measured	Panorex cassette holder slot dimensions	X-ray beam dimensions (from film)
Length	5-1/16 in.	5 in.(5⅛ in.[a])
Width	7 mm	8.3 mm

[a]Longer side (see figure 17).

The results indicate that the width of the beam exceeds that of the slit in the cassette holder. Since the slit in the collimator conforms to the manufacturer's specifications, this broadening of the beam is most likely a result of off-focus radiation.

The significance of the x-ray beam being larger than the cassette holder slit is minimal. Experiments indicated that this condition had no appreciable deleterious effect on film sharpness and would not result in significant unnecessary patient exposure. In addition, because the film in the cassette holder is exposed only to the most homogeneous portion of the x-ray beam and the low-intensity extremes are excluded, the quality of the radiographs produced may actually be better than if the entire beam were used. Based on these considerations, no further limitation of the dimensions of the x-ray beam would appear to be necessary.

9. EXCURSION TIME AND EXPOSURE REPRODUCIBILITY

9.1 X-RAY ON-TIME

The total excursion of the Panorex tubehead can be divided into four distinct segments. They are:

(1) X-ray tube energizing time: the period between commencement of the excursion and the first production of radiation.

(2) First half of the radiographic scan of orofacial and associated anatomical structures.

(3) Chair-shift time, during which no radiation is produced.

(4) Second half of the radiographic scan.

The most important of these are the two halves of the radiographic scan which, combined, compose the x-ray on-time. To determine the reproducibility of this quantity, the following were measured in turn:

(A) Total excursion time: (1) through (4)

(B) Chair-shift time: (3)

(C) X-ray on-time plus chair-shift time: (2) through (4)

The x-ray on-time (C - B) was then calculated.

The technique employed in these measurements involved the connection of an Industrial Timer Corporation Timer, model SC-100, into various parts of the Panorex control circuitry. The timer was activated when the circuit of interest closed and deactivated when it opened. To measure the total excursion time, the timer was connected into the excursion motor circuit, and the chair-shift time was measured with the connection made to the chair-shift motor relay terminals. The x-ray on-time plus chair-shift time was measured by means of the time-delay assembly.

The original plan was to measure each of the three quantities (A,B,C) 10 times. However, it became apparent during the measurement of the total excursion time that there was a significant difference between the length of the excursions in the clockwise (CL) and counterclockwise (CCL) directions. For this reason, (A) and (C) were each measured 20 times (10 times during clockwise and 10 times during counterclockwise excursions). This was not found to be necessary for (B) which was measured only 10 times (five in each direction). The resulting means and standard deviations are presented in table 4.

Table 4. Excursion time reproducibility.

Quantity [a]	Mean (seconds)	Standard deviation (percent)
Total excursion time		
CL (A)	22.61	<<1.0
CCL (A')	21.84	<<1.0
Chair-shift time		
CL (B)	1.64	1.0
CCL (B')	1.65	1.8
Average (B")	1.65	1.4
X-ray on-time plus chair-shift time		
CL (C)	21.68	<1.0
CCL (C')	21.00	<1.0
X-ray on-time		
CL (C - B")	20.03	<1.0
CCL (C' - B")	19.35	<1.0

[a] CL = clockwise
CCL = counterclockwise
(A), (B), (C) as defined on page 28

All the data obtained are extremely reproducible. In addition, several observations are worthy of note. The clockwise excursion is approximately 0.8 second longer than the counterclockwise excursion, mainly as a result of the difference in x-ray on-time in the two directions. Such a time difference is to be expected, however, as it is virtually impossible to design an excursion motor which will run exactly the same in opposite directions. This time difference is insignificant in terms of the diagnostic information obtained from Panorex radiography. How it affects the amount of radiation produced per excursion is examined in paragraph 9.2 which follows.

9.2 EXPOSURE REPRODUCIBILITY

Because of the difference in x-ray on-time noted above, the exposure reproducibility was determined separately for each excursion direction. Five exposures in each direction were made at 90 kVp and 10 mA. The radiation detectors were Victoreen Model 570 condenser R-meter chambers taped in a fixed position in front of the slot in the cassette holder.

Measurements were made with a 25-R chamber and repeated with a 10-R chamber. As the chambers were not completely covered by the x-ray beam, the measured values represent relative exposures only. The standard deviations of the exposures are shown in table 5.

Table 5. Exposure reproducibility

Chamber	Direction	Mean (exposure units per excursion)[a]	Standard deviation (percent)	Difference between exposures (percent)	Average difference between exposures (percent)
25 R	Clockwise	4.87	1.6	4.7	4.5
	Counter-clockwise	4.65	1.1		
10 R	Clockwise	3.74	1.5	4.2	
	Counter-clockwise	3.59	1.0		

[a]Measured at front of cassette holder.

The exposures exhibited excellent reproducibility. The clockwise exposures are about 4.5 percent higher than the counterclockwise ones, which is in satisfactory agreement with the 3.5 percent difference between the x-ray on-times in the two directions. Hence, the exposure rates in the two directions are approximately the same. The difference in exposure length is unlikely to have any effect on the resulting radiographs because sufficient areas are present, both at the beginning and end of the films, which contain no significant information. However, the knowledge of the existence of this difference is important for beam quality determinations made during radiation protection surveys of these units. If complete excursions are used as individual exposures, those made in opposite directions are not comparable for purposes of determining an absorption curve. Further consideration is given to this matter in section 11.

10. STRAY RADIATION

Stray radiation is defined as the sum of leakage and scattered radiation *(8)*. Because of the difficulties involved in locating the sources of leakage and shielding them, it is almost impossible to measure the scattered radiation separately when there is any significant leakage emanating from the tubehead. For this reason, the stray radiation and the leakage radiation from the Panorex were measured individually, and the scattered radiation component was ascertained from their difference.

Stray radiation was measured with the upper portion of a Rando phantom seated in the chair and the head properly positioned in the Panorex Pancentric Head Positioner (fig. 18). Thermoluminescent dosimeters were positioned on two horizontal cardboard planes, approximately 1.5 inches below the x-ray beam, under the chin, and 32 inches above the floor (fig.19). Dosimeters were placed in a semicircle based on an assumption of symmetry around the major axis (0 degrees).

Both LiF and CaF_2 chips, approximately 3-mm square by 0.1-mm thick, were used as dosimeters. The CaF_2 dosimeters were selected as the primary means of measurement because of their higher sensitivity. The LiF dosimeters, because of their essentially energy-independent response, were used to calibrate the CaF_2 dosimeters. Initial calibration of the LiF chips was accomplished with a G.E. Maximar-100 x-ray machine whose waveform, kilovoltages, and filtration were similar to those of the Panorex. Then both the LiF and CaF_2 dosimeters were placed in certain radial positions close to the phantom, and the measured exposures to the LiF chips were used to calibrate the CaF_2 chips which were alone at all other positions.

The LiF and CaF_2 dosimeters were used in groups of three and two, respectively. A total of 40 exposures (excursions) was made at 90 kVp and 13 mA for this experiment. These are the highest settings recommended in the manufacturer's technique chart (see appendix B).

The dosimeters were read, and the data were plotted as mR versus distance along each radial. These curves were used to construct the isoexposure curves in figure 20. The highest level of stray radiation occurred at 90 degrees, and the lower plane received generally higher exposures.

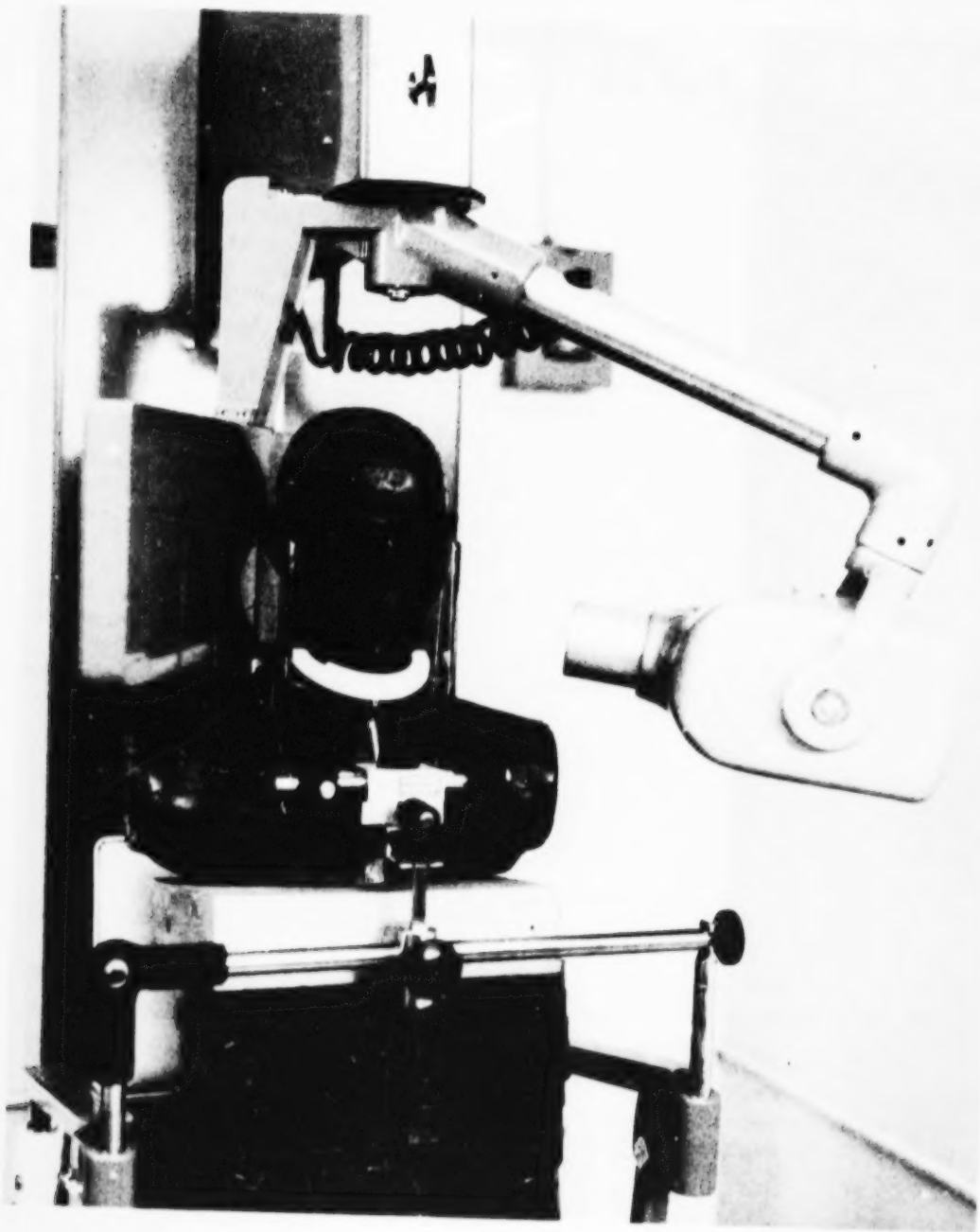


Figure 18. Phantom positioned in the Panorex.

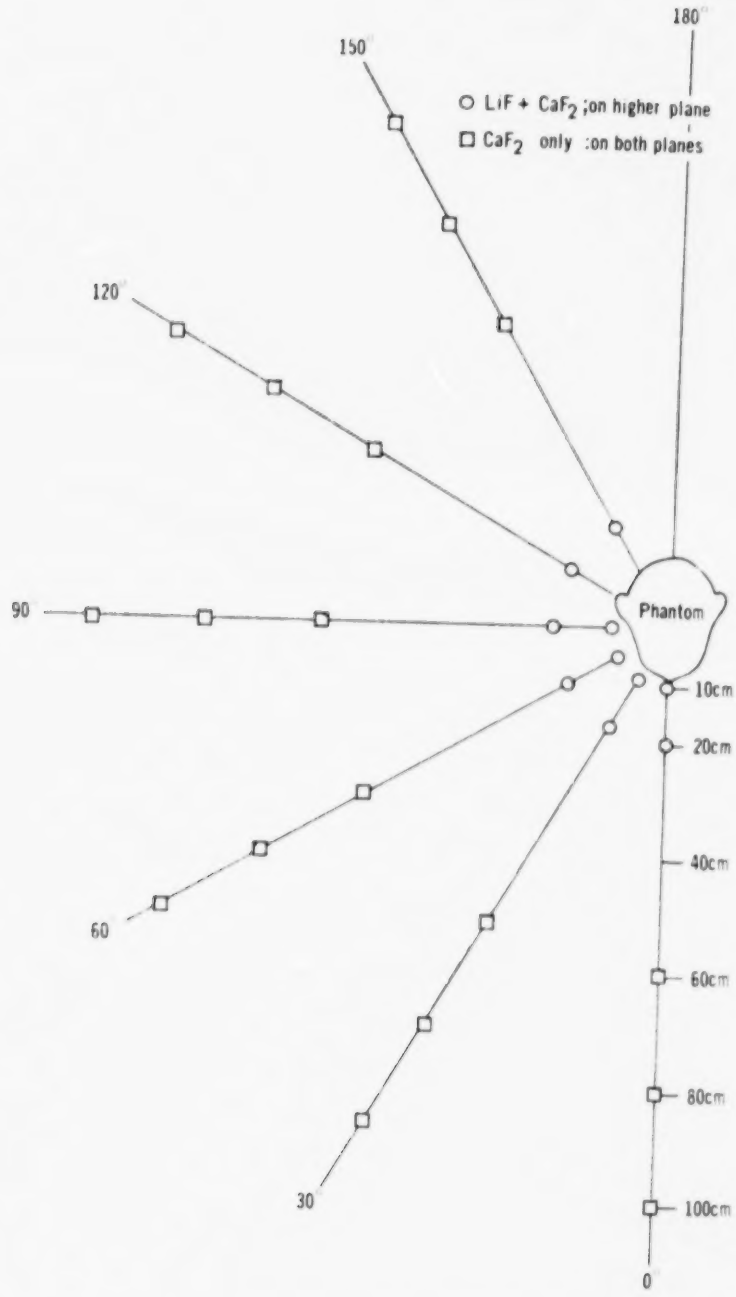


Figure 19. Arrangement of thermoluminescent dosimeters around phantom.

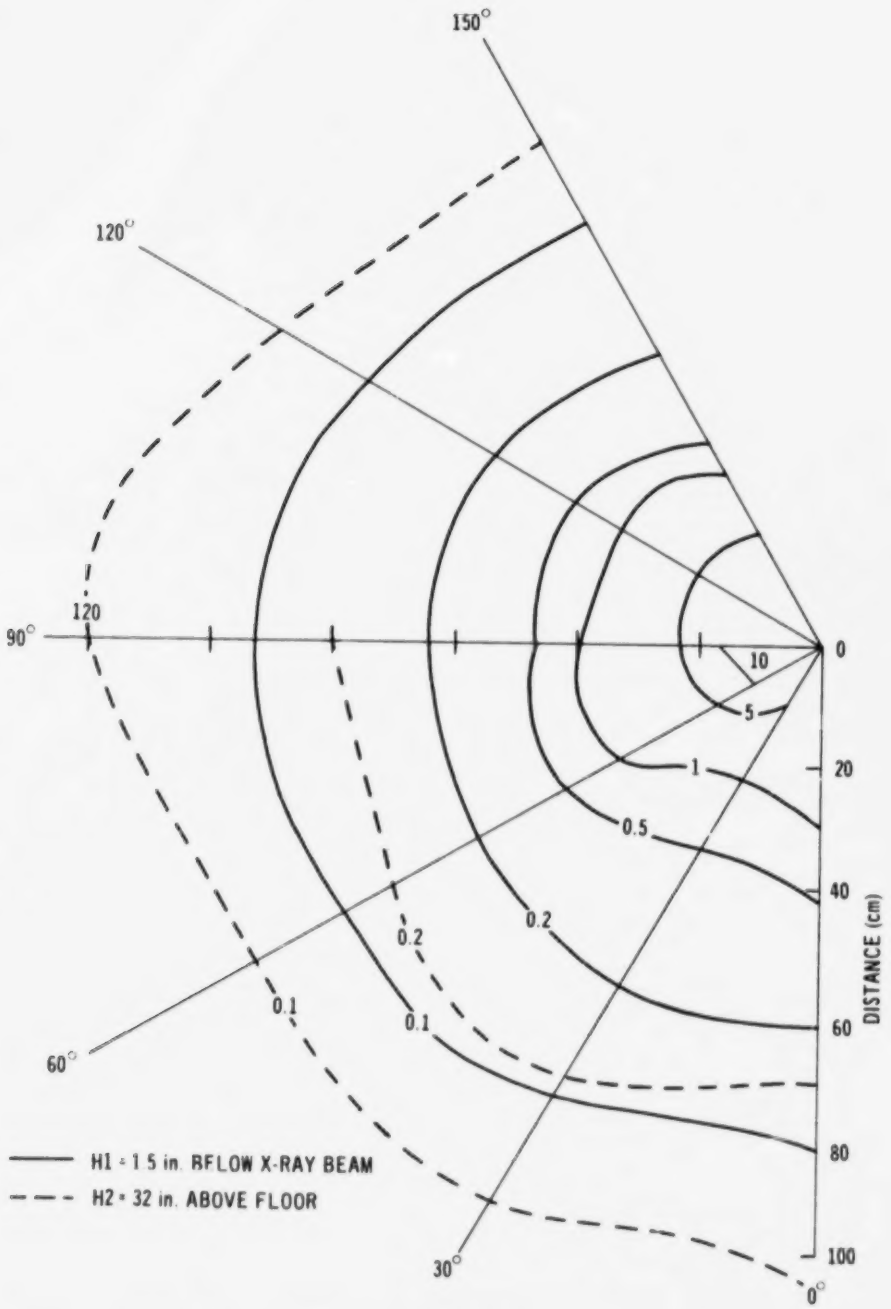


Figure 20. Stray radiation isoexposure curves: mR per excursion at 90 kVp.

To measure the leakage radiation from the tubehead, the phantom was removed from the chair, the exit slit in the collimator was blocked with 20 half-value layers of lead, and the above experiment was repeated. One series of dosimeters at a common radial distance (80 cm) was omitted. The only additional dosimeters were two groups of eight LiF chips placed around the collimator at both ends, the juncture with the tubehead and the front face. Twenty exposures (excursions) were made for this experiment.

As before, the dosimeters were read, and the isoexposure curves shown in figure 21 were constructed. Exposures recorded at the lower level were all below 0.03 mR/excursion and were too low to be meaningfully displayed on curves. The levels of leakage were well within allowed limits.

To obtain data for scattered radiation alone, the exposure values from leakage radiation were subtracted from the corresponding stray radiation measurements. These new values were then treated as above, and isoexposure curves for scattered radiation were constructed. These curves appear in figure 22. They exhibit much the same form as those for stray radiation, as might be expected since scattered radiation was its major component.

At all positions except those extremely close to the patient, the levels of stray radiation around the patient are very low. Hence, only minimal safety precautions are needed in the use of the Panorex. The primary concern is that the control panel should always be located at least a meter from the Panorex base. In addition, persons routinely remaining very close to the patient during radiography should be protected by lead aprons.

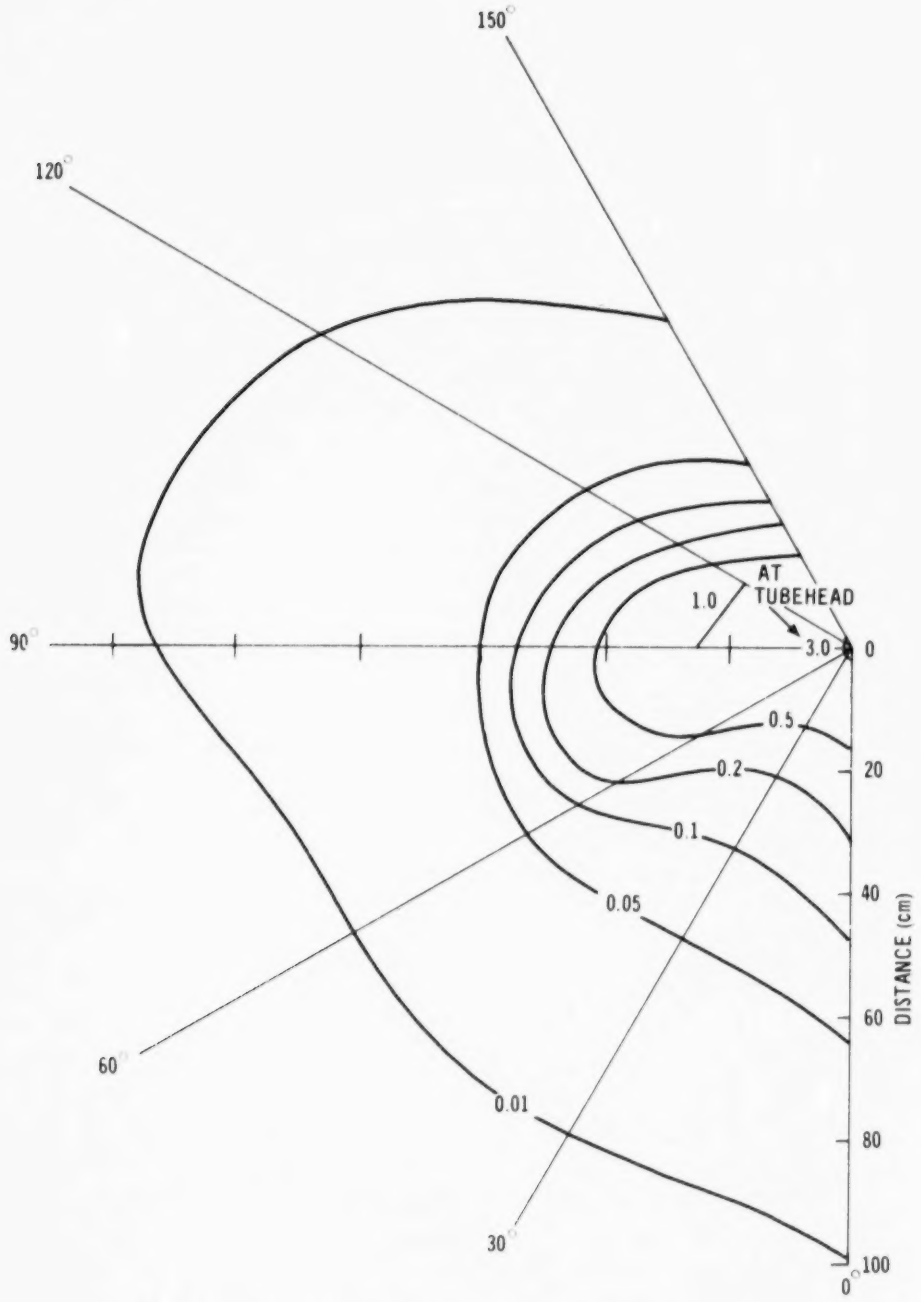


Figure 21. Leakage radiation at 1.5 inches below x-ray beam isoexposure curves: mR per excursion at 90 kVp.

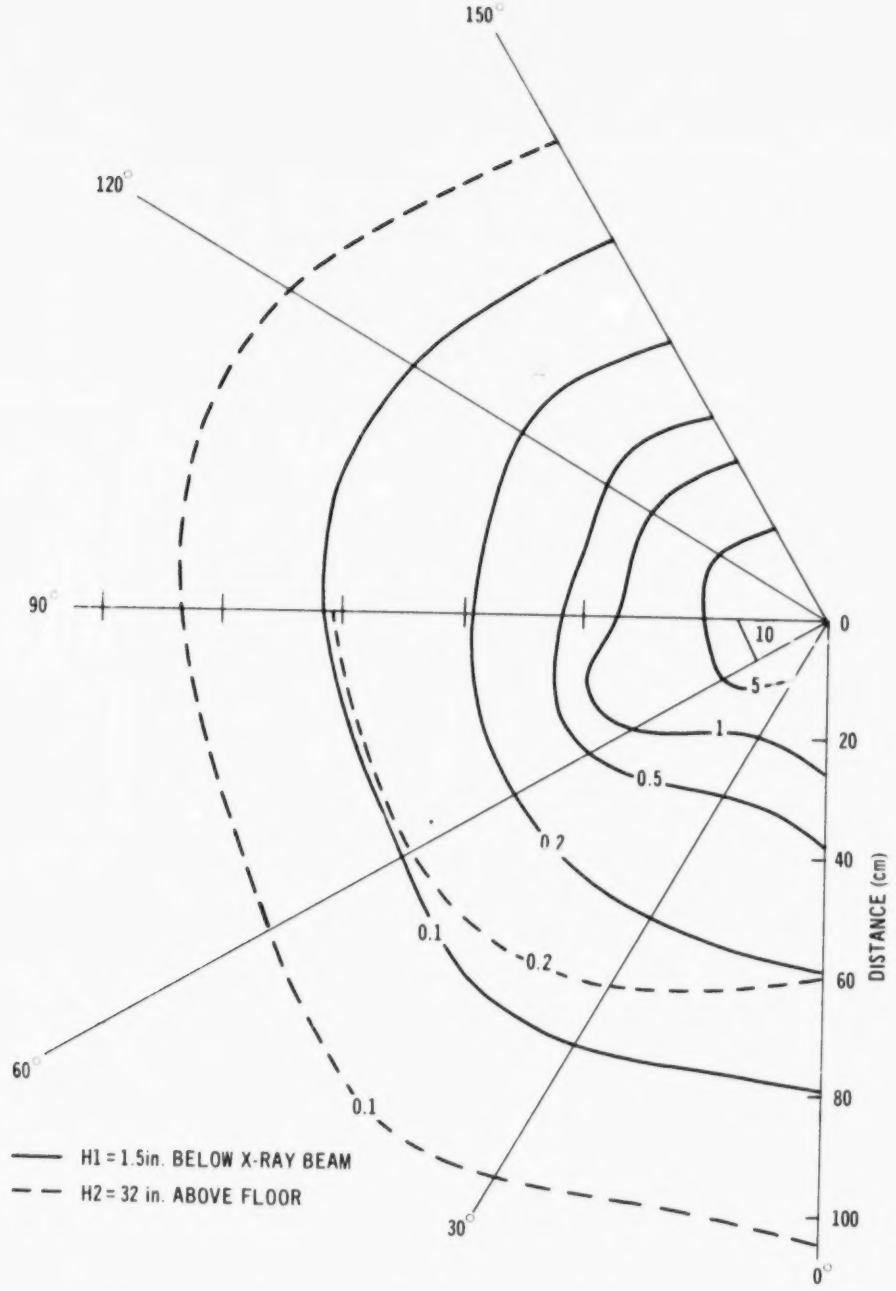


Figure 22. Scattered radiation isoexposure curves: mR per excursion at 90 kVp.

11. DETERMINATION OF BEAM QUALITY AND FILTRATION

Because of the unique nature of the Panorex and its narrow x-ray beam, considerable interest has been exhibited in methods of determining beam quality in order to estimate filtration. Unlike conventional dental x-ray machines in which the added filtration can be determined simply by removing the collimator and measuring the filtration, the importance of accurate x-ray beam alignment and the considerable difficulty involved in realignment once the collimator has been removed makes this an impractical routine procedure for the Panorex. An alternative method of determining filtration is to measure the half-value layer of the beam and then apply the table of half-value layers versus filtration which appears in NCRP Report No. 35*(8)*. This table can also be used to determine merely whether minimum filtration requirements have been met. The half-value layer corresponding to the required amount of filtration is obtained from the table, and if introduction of this thickness of aluminum into the x-ray beam reduces the measured exposure rate by 50 percent or less, minimum filtration requirements have been satisfied.

The goal of this investigation was to discover survey techniques which would yield half-value layer results comparable to those obtained with the Victoreen 555 radiation measuring instrument and which would allow performance of the minimum filtration test with confidence.

The following instruments were investigated in connection with possible survey techniques: Victoreen Model 570 condenser R-meter (25-R, 10-R, 5-R chambers), Victoreen Model 666 (diagnostic chamber), Nuclear Associates Model CS-40A, and Bendix Low Energy Pocket Dosimeters (5-R, 20-R chambers). The chambers were taped vertically over the slot in the cassette holder, and the filters were attached to the end of the collimator. The results indicated that the smaller the dosimeter (and thus the more nearly it was completely covered by the x-ray beam), the closer the measured half-value layers were to those established under conditions of good geometry. The larger ionization chambers yielded results that were as much as 30 percent high when compared to those obtained with the Victoreen 555 under the conditions described in section 6. For this reason, the survey instruments of choice were the Victoreen 25-R and 10-R chambers and the Bendix 20-R and 5-R dosimeters, the coverage of which by the x-ray beam was sufficient to produce reliable results. The Victoreen chambers were found to be more suitable for making half-value layer measurements because of their high precision, while both instruments performed satisfactorily for determination of minimum filtration.

The conditions of half-value layer measurement with the condenser R-chambers were as follows: The chamber was taped vertically to the cassette holder so that the sensitive volume was centered in the x-ray beam, and aluminum type-1100 alloy absorbers were taped to the end of the cone. For each absorber thickness, the same number of exposures was made per reading (an exposure is defined here as one excursion of the tubehead). The number of exposures was chosen so that all the readings were in the middle two-thirds of the condenser R-meter scale.

All readings were composed of exposures made either all in the same cycling direction or in pairs, one in each direction. This was done to negate the effect of x-ray on-time differences mentioned earlier (see paragraphs 9.1 and 9.2). Exposures were made at 90 kVp and either 10 or 13 mA to maximize readings; two and one exposures per reading were made for the 25-R and 10-R chambers, respectively. The time allowed between exposures was 3 minutes.

To minimize the time required for this procedure, only three readings are needed to arrive at an estimate of the half-value layer. With the chamber in position and no added filtration, the first exposure(s) is made. After the dosimeter is removed and read, it is replaced in the same position, and the first filter packet is attached to the cone. Given some idea of what the half-value layer is, this packet is chosen to be within about 0.5 mm of that value (2 mm is a good choice). Exposures and a second reading are made. If the ratio of the two readings indicates that the half-value layer has not been reached, another 0.5-mm filter is added to the packet. If the half-value layer has been exceeded, the same amount is removed from the packet. When the third reading is completed, there should then be one reading above the half-value layer and one below it. If this has still not been achieved, an additional 0.5 mm should be added or removed from the filter packet, as appropriate, and a fourth reading taken. The approximate half-value layer can then be determined graphically or by interpolation.

Measurements with the Bendix dosimeters were accomplished in essentially the same manner as for the condenser R-chambers. The dosimeters were charged, attached to the cassette holder, exposed, and read. Exposures for the 5-R chamber were made at 70 and 80 kVp and 10 mA to obtain on-scale readings. One exposure per reading was made for the 5-R chamber, while two exposures were used for the 20-R chamber in order to obtain mid-scale readings.

The minimum filtration test is easily performed. A peak tube potential is chosen, and the half-value layer corresponding to the required amount of filtration is determined from the table in NCRP Report No. 35 *(8)*. For example, for 2.5 mm Al filtration, the half-value layer

at 90 kVp is approximately 2.6 mm Al. A packet of aluminum filters equal in thickness to the appropriate half-value layer is prepared. The dosimeters are positioned as described above, exposures and readings are made with and without this filter packet attached to the cone, and the ratio of the exposure readings (with filter/without filter) is calculated. If this ratio is greater than or equal to 0.5, the unit has sufficient total filtration and the requirement has been met.

The half-value layer results obtained with the 25-R and 10-R Victoreen chambers and the 20-R and 5-R Bendix chambers are shown in Table 6 along with corresponding "true" results obtained by the method described in section 6. Both condenser R-chambers provide results with errors of 5 percent or less, while the accuracy of the Bendix chambers is somewha poorer. The 25-R chamber appears to yield the greatest accuracy, but this chamber has the drawback that it requires twice as long to produce these results as does the 10-R chamber.

Nevertheless, both condenser R-chambers provide acceptable accuracy for half-value layer and are the instrument of choice for such determinations. For the "go/no go" filtration test, both Victoreen and Bendix chambers are acceptable. However, since the high precision provided by the R-chambers is not essential, the Bendix chambers are the more economical choice.

Table 5. Half-value layer by survey method.

Indicated kVp	mA	"True" half-value layer (mm Al)	Chamber	Measured half-value layer (mm Al)	Error (percent)
90	10	1.90	Victoreen 25 R	1.95	3
			Victoreen 10 R	2.00	5
			Bendix 20 R	1.71	10
90	13	1.80	Victoreen 25 R	1.76	2
			Vicotreen 10 R	1.83	2
80	10	1.65	Bendix 20 R	1.59	4
			Bendix 5 R	1.82	10
70	10	1.45	Bendix 5 R	1.62	12

12. OPERATIONAL OBSERVATIONS AND COMMENTS

During the course of this study, mechanical irregularities in various components of the Panorex were observed. Most of these were very minor and had little if any effect on the operation of the unit, but they did serve as annoyances and occasional temporary hindrances. Several of the irregularities that appeared are discussed below.

Instability was often observed in the kVp and mA meters during the course of x-ray exposures. Even though the proper adjustment was made at the start of testing so that the kVp meter read the same before and during exposures as described in the Panorex installation and service manual, this problem recurred within a short period of time and the adjustment had to be repeated. In addition, the mA meter often showed considerable instability, varying by more than 0.5 mA during a single exposure cycle. Usually the reading decreased gradually as the cycle continued. This variation occurred even though the line voltage to the unit was maintained constant by a voltage regulator. These fluctuations of the kVp and mA meters had no noticeable effect on any of the tests performed on the Panorex.

Several other observations were made during the evaluation. Almost from the start, the "dead-man" type exposure switch occasionally malfunctioned in such a manner that the operator could release his pressure on it without interrupting the exposure. Application of a small amount of lubricant to the rear of the switch was recommended as a corrective measure by the manufacturer. Also, the radiation light on the control panel remained on during the chair shift, even though the mA meter clearly indicated that no radiation was produced during this time. Information about the Panorex indicated that this condition was normal.

Erratic performance in the excursion drive system appeared in the later stages of testing and caused the tubehead to rotate unevenly and occasionally to halt. Initially, the procedure suggested in the service manual for correcting this difficulty proved unsuccessful, and even when it later produced the desired result, the solution was not permanent. Since erratic excursions may produce unacceptable radiographs, this is a significant difficulty. The service manual should provide more explicit instructions for dealing with the problem and should include a recommendation for obtaining servicing of the unit if necessary.

During this evaluation it was found that the locking pin which was designed to hold the tubehead-cassette carrier assembly motionless when the Panorex was not in use could easily be left in place when the excursion switch was engaged. Because this accidental occurrence could cause damage to the excursion drive system, it was concluded that an improved locking pin system should be developed. Conversations with the manufacturer subsequent to the completion of this evaluation have indicated that future models of the Panorex will employ an interlocked locking pin system.

13. CONCLUSIONS AND RECOMMENDATIONS

13.1 RECOMMENDATIONS TO THE MANUFACTURER

Based upon the results of this study, the following recommendations were advanced for possible action by the manufacturer:

(1) An additional amount of aluminum filtration should be added in the tubehead to ensure that all units have the recommended 2.5 mm Al filtration for units that operate above 70 kVp. The unit tested was deficient in this respect.

(2) The kVp meter operating at the usual tube current (10 mA) should be calibrated to correspond more closely to actual kVp. The significant inaccuracy of this meter results in confusion as to proper exposure settings and total filtration estimates from half-value layer data.

(3) A means for making the tube current more stable should be sought. Systems for setting the mA control prior to patient exposure should be considered.

(4) The technical feasibility of alterations to make the x-ray on-time the same in both cycle directions should be investigated.

In response to these recommendations and as a result of technological developments, the manufacturer provided the following information:

(1) An additional aluminum filter of 0.5 mm is being added to all Panorex units. This applies to both new units manufactured after August 18, 1971, and those currently in the field.

(2) The Panorex technique chart specifies operation at 5 mA for units employing cassettes loaded with Super Pan-O-Screens. The measured kVp of the unit tested deviated from the kVp meter reading by only 2 to 3 kVp at this tube current.

(3) Improved methods of milliampere stabilization are being investigated for possible incorporation into future models of the Panorex.

(4) Based upon technical considerations, alterations to eliminate the x-ray on-time difference are not feasible.

13.2 RECOMMENDED SURVEY TECHNIQUES

Based upon the tests described in this report, the following survey techniques are recommended for determination of beam quality:

(1) An ionization chamber with a small diameter should be used. Results of tests with a 3-cm-diameter chamber were found to be unsatisfactory. Recommended chambers are the Victoreen 25-R and 10-R condenser-R meter chambers and the Bendix 20-R and 5-R low-energy dosimeters, the largest of which has a diameter of 1.8 cm.

(2) Aluminum absorbers should be affixed to the collimator, and the ionization chamber should be attached to the front of the cassette carrier such that its longitudinal axis is parallel to and centered in the slit. The same integer number of excursions should make up each exposure, and all excursions should be made in the same direction.

(3) The kVp and mA meters should be observed during each exposure. If the kVp and mA fluctuate significantly, the exposure should be repeated.

(4) An attenuation curve may be generated to determine the half-value layer. A minimum filtration test may be performed by making two measurements, one with no added absorbers and one with added absorber thickness corresponding to the known half-value layer for a given total filtration and kVp. In both cases the tables of half-value layer versus total filtration in NCRP Reports #33 *(11)* and #35 *(8)* should be used.

REFERENCES

(1) PAATERO, Y.V. New tomographical method for radiographing curved outer surfaces. Acta Radiologica 32:177-184 (1949).

(2) HUDSON, D.C., J.W. KUMPULA, and G. DICKSON. Panoramic dental x-ray machine. U.S. Armed Forces Medical Journal 8:46-55 (January 1957).

(3) HODGES, P.C. Tomography. Postgraduate Medicine 41:A57-A62 (February 1967).

(4) UPDEGRAVE, W.J. Panoramic dental radiography. Dental Radiography and Photography 36:77 (1963).

(5) MACLEAN, H.R. Current status of panoramic radiography. Journal of the Canadian Dental Association 32:346 (1966).

(6) S.S. WHITE COMPANY. Panorex Operating Manual.

(7) TROUT, E.D., J.P. KELLEY, and A.C. LUCAS. Determination of half-value layer. Am J Roent Rad Ther Nuc Med 84(4): 729-740 (October 1960).

(8) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENT. NCRP Report No. 35, Dental X-ray Protection. Washington, D.C. (March 1970)

(9) NATIONAL BUREAU OF STANDARDS. NBS Handbook 89, Methods of evaluating radiological equipment and materials. (August 1963).

(10) S.S. WHITE COMPANY. Panorex Installation and Service Manual.

(11) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENT, NCRP Report No. 33, Medical x-ray and gamma-ray protection for energies up to 10 MeV. Washington, D.C. (February 1968).

APPENDIX A

MANUFACTURER'S SPECIFICATIONS FOR THE PANOREX X-RAY MACHINE

Preceding page blank

APPENDIX A

MANUFACTURER'S SPECIFICATIONS FOR THE PANOREX X-RAY MACHINE

Manufacturer	S. S. White Dental Health Products (a division of Penwalt Chemical Co.)
Trade name	Panorex®
Electrical requirements	100 to 130 volts, 16 amps, 50/60 Hz, single-phase AC source supplied on two #12 line wires (a separate ground wire must be provided), machine draws 1300 watts at capacity for 20 seconds.
Focal spot size	0.8-mm square
Tube rating	90 kVp at 14 mA
Duty cycle	100 seconds between exposures; i.e., 30 patients per hour (8-hour day, no fan, 70° ambient temperature)
Tube potential	50 to 90 kVp, adjustable
Tube current	0 to 14 mA, adjustable
X-ray beam width	1.5 mm

Preceding page blank

APPENDIX B

PANOREX OPERATING PROCEDURE

Preceding page blank

APPENDIX B

PANOREX OPERATING PROCEDURE

The Panorex operator's manual *(6)* recommends that the following procedures be used to achieve uniform results:

(1) Place the cassette carriage cable in the proper groove of the child-adult cam.

(2) Place the loaded cassette into the cassette holder.

(3) Turn on the main switch.

(4) Measure the lateral width of the face at the tragus of the ear with a caliper, and refer this measurement to the exposure technique guide (table B-1) to obtain the correct kVp and mA for cassettes containing Pan-O-Screens[1] or kVp alone for cassettes supplied with Super Pan-O-Screens[1].

(5) Adjust the kilovolts corresponding to the measurement in step 4.

(6) Position the patient in the chair and lock the chin rest in place.

(7) With the patient sitting erect, position the auxiliary cushion between the patient's back and the back rest on the chair.

(8) Adjust the vertical height of the chin rest assembly so that a line drawn from the tragus of the ear to the ala of the nose is tilted approximately 5 degrees down and forward. The patient's occlusal plane will now be parallel to sloping lines inscribed on the front surface of the cassette holder.

(9) Position the patient's head symmetrically on the chin rest with the midsagittal plane located directly behind the black line on the chin rest.

(10) Adjust the vertical height of the cassette holder by moving the horizontal arm assembly until the reading of the scale on the left side of the shroud corresponds to the same reading on the vertical chin rest rod. The horizontal support arm assembly is lowered or raised by depressing both the hand switch on the left side of the chair and the proper side of the foot switch.

[1] DuPont Screens

Preceding page blank

(11) After rechecking the tragus-ala line angulation, remove the locking pin located on the front of the horizontal support arm.

(12) Insert bite tab (cotton roll or midline locator) to prevent overlap.

(13) Turn on the radiation switch, checking the kVp setting.

(14) Push and hold the directional switch, checking the mA setting until the cassette holder assembly automatically stops rotating. The exposure for the panoramic radiograph has now been completed.

(15) Turn off the radiation switch.

(16) Release the patient and remove the cassette from the cassette holder.

(17) If another patient is to be radiographed, the above procedure is repeated. If not, the locking pin must be reinserted into the horizontal arm support.

(18) Turn off the main switch.

Table B-1. Exposure technique guide. *(6)*

Lateral width of face at tragus of ear (cm)	Pan-O-Screens		Super Pan-O-Screens	
	Kilovolts	Milliamperes	Kilovolts	Milliamperes
9	64	10	59	5
10	68	10	63	5
11	70	10	67	5
12	74	10	70	5
13	78	10	73	5
14	82	10	77	5
15	86	10	80	5
16	90	10	84	5
17	90	13	88	5

The ABSTRACT CARDS below are designed to facilitate document retrieval using Coordinate Indexing. They provide space for an accession number (to be filled in by the user), suggested key words, bibliographic information, and an abstract.

The Coordinate Index concept of reference material filing is readily adaptable to a variety of filing systems. Coordinate Indexing is described in the publication "IBM Data Processing Techniques - Index Organization for Information Retrieval" (C20-8062). Copies are available through IBM Branch Offices.

The cards are furnished in triplicate to allow for flexibility in their use (e.g., author card index, accession number card index).

Arnold F. Jacobson and John P.Ferguson
EVALUATION OF THE S.S. WHITE PANOREX® X-RAY MACHINE.

Accession No.

USDHEW, Public Health Service,Food and Drug Administration, Bureau of Radiological Health. DHEW Publication No. (FDA) 72-8020, BRH Publication No. BRH/DEP 72-6 (December 1971) 54 pp. (limited distribution).

ABSTRACT: An evaluation of the S.S. White Panorex® dental x-ray machine was performed. The physical and operational characteristics of the unit were investigated with particular emphasis on kVp and mA meter calibrations, focal spot characteristics, x-ray beam dimensions, half-value layers, and inherent filtration. Isoexposure curves for radiation in the vicinity of a phantom were determined, and survey techniques for half-value layer

(over)

Arnold F. Jacobson and John P.Ferguson
EVALUATION OF THE S.S. WHITE PANOREX® X-RAY MACHINE.

Accession No.

USDHEW, Public Health Service,Food and Drug Administration, Bureau of Radiological Health. DHEW Publication No. (FDA) 72-8020, BRH Publication No. BRH/DEP 72-6 (December 1971) 54 pp. (limited distribution).

ABSTRACT: An evaluation of the S.S. White Panorex® dental x-ray machine was performed. The physical and operational characteristics of the unit were investigated with particular emphasis on kVp and mA meter calibrations, focal spot characteristics, x-ray beam dimensions, half-value layers, and inherent filtration. Isoexposure curves for radiation in the vicinity of a phantom were determined, and survey techniques for half-value layer

(over)

Arnold F. Jacobson and John P.Ferguson
EVALUATION OF THE S.S. WHITE PANOREX® X-RAY MACHINE.

Accession No.

USDHEW, Public Health Service,Food and Drug Administration, Bureau of Radiological Health. DHEW Publication No. (FDA) 72-8020, BRH Publication No. BRH/DEP 72-6 (December 1971) 54 pp. (limited distribution).

ABSTRACT: An evaluation of the S.S. White Panorex® dental x-ray machine was performed. The physical and operational characteristics of the unit were investigated with particular emphasis on kVp and mA meter calibrations, focal spot characteristics, x-ray beam dimensions, half-value layers, and inherent filtration. Isoexposure curves for radiation in the vicinity of a phantom were determined, and survey techniques for half-value layer

(over)

measurements and x-ray beam alignment were investigated. Recommendations based on the observed operation of the Panorex are advanced.

KEYWORDS: Panoramic X-ray Machines; Radiation Safety; X-ray Machine Evaluation; X-ray Machine Safety.

measurements and x-ray beam alignment were investigated. Recommendations based on the observed operation of the Panorex are advanced.

KEYWORDS: Panoramic X-ray Machines; Radiation Safety; X-ray Machine Evaluation; X-ray Machine Safety.

measurements and x-ray beam alignment were investigated. Recommendations based on the observed operation of the Panorex are advanced.

KEYWORDS: Panoramic X-ray Machines; Radiation Safety; X-ray Machine Evaluation; X-ray Machine Safety.

DIVISION OF ELECTRONIC PRODUCTS

Technical Reports

(continued from inside of front cover)

Title

BRH/DEP 70-23 Microwave Oven Test Load Evaluation and Determination of Internal Microwave Energy Distribution (August 1970) (NTIS no. PB 193 804, $3.00)

BRH/DEP 70-24 In-Plant Survey of Television Receivers for X-radiation Emission Capability (September 1970) (NTIS no. PB 194 316, $3.00)

BRH/DEP 70-25 Laboratory Testing and Evaluation of Microwave Ovens (October 1970) (NTIS no. PB 194 484, $3.00)

BRH/DEP 70-26 Electronic Product Radiation and the Health Physicist - Health Physics Society Fourth Annual Midyear Topical Symposium (October 1970) (NTIS no. PB 195 772,$6.00)

BRH/DEP 70-27 A Study of Head and Neck Exposure from Polytomography (November 1970) (NTIS no. PB 195 702, $3.00)

BRH/DEP 70-28 Present Federal Control of Health Hazards from Electronic Product Radiation and Other Types of Ionizing Radiation (November 1970) (NTIS no. PB 195 969, $3.00)

BRH/DEP 70-29 Electronic PRoduct Inventory Study (November 1970) (NTIS no.PB 195 968, $3.00)

BRH/DEP 70-30 A Study to Determine the Necessity for the Development of Standards for the Use of Selected Nonmedical Electronic Products for Commercial and Industrial Purposes (December 1970) (NTIS no. PB 196 448, $3.00)

BRH/DEP 70-31 Inexpensive Readout for a Commercial Thermocouple Microwave Power Density Probe (December 1970) (NTIS no. PB 196 440, $3.00)

BRH/DEP 71-1 Microwave Measurement and New Types of Detectors for Evaluation of Health Hazards (January 1971 (NTIS no. PB 197 715, $3.00)

BRH/DEP 71-2 Electronic X-ray Pulse Counter (January 1971) (NTIS no. PB 197 793, $3.00)

BRH/DEP 71-3 Evaluation of the Picker Capacitor Discharge Mobile X-ray Machine (February 1971 (NTIS no. PB 198 080, $3.00)

BRH/DEP 71-4 A Radiation Survey of Television Repair Shops in the Baltimire Area (March 1971) (NTIS no. PB 198 240) (GPO $0.50)

BRH/DEP 71-5 Electromagnetic Radiation Interference with Cardiac Pacemakers (April 1971) (NTIS no. PB 199 160) (GPO $0.45)

BRH/DEP 71-6 Evaluation of Lithium Fluoride for Microwave Dosimetry Applications (April 1971) (NTIS no. PB 198 406, $3.00)

BRH/DEP 71-7 Construction and Evaluation of a Kit-Form Microwave Oven (May 1971) (NTIS no. PB 200 102) (GPO no. 1715-0016, $0.35)

BRH/DEP 71-8 Evaluation of the Westinghouse Capacitor Discharge Mobile X-ray Machine (May 1971) (NTIS no. PB 200 400) (GPO no. 1715-0018, $0.35)

BRH/DEP 72-1 Evaluation of the Toshiba Capacitor Discharge Mobile X-ray Machine (August 1971) (NTIS no. PB 202 925) (GPO no. 1715-0024, $0.35)

BRH/DEP 72-2 Results of the 1970 Microwave Oven Survey (August 1971) (NTIS no. PB 202 867) (GPO no. 1715-0023, $1.25)

BRH/DEP 72-3 Radiation Safety in X-ray Diffraction and Spectroscopy (September 1971) (NTIS no. PB 203 577) (GPO $2.00)

BRH/DEP 72-4 Measurement of Electromagnetic Radiation Levels from Selected Transmitters Operating Between 54 and 220 MHz in the Las Vegas, Nevada, Area (September 1971) (GPO $0.75)

BRH/DEP 72-5 Radiofrequency and Microwave Radiation Levels Resulting from Man-Made Sources in the Washington, D.C., Area (October 1971)

BRH/DEP 72-6 Evaluation of the S. S. White Panorex X-ray Machine (December 1971)